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STRATIGRAPHY AND DEPOSITIONAL ENVIRONMENTS OF THE MIDDLE DEVONIAN WATT MOUNTAIN FORMATION UTIKUMA LAKE AREA, ALBERTA

BY ©

JOHN BOURAK

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF MASTER OF SCIENCE

DEPARTMENT OF GEOLOGY

EDMONTON, ALBERTA
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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled STRATIGRAPHY AND DEPOSITIONAL ENVIRONMENTS OF THE MIDDLE DEVONIAN WATT MOUNTAIN FORMATION UTIKUMA LAKE AREA, ALBERTA submitted by JOHN BOURAK in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE.

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Dr. S. G. Pemberton

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Date August 16, 1993

ABSTRACT

Within the Nipisi field area located in north-central Alberta, Middle Devonian Watt Mountain Formation sediments accumulated in a north-south trending trough shaped feature. This Muskeg trough evolved throughout Middle Devonian time as a result of salt solution collapse in the underlying Muskeg Formation. The Muskeg trough fill consists of six cycles of deposition which record the progradation and abandonment of lacustrine braid-delta deposits.

Four recurring facies associations collectively suggest that the Watt Mountain Formation sediments in the Muskeg trough fill were deposited in a lacustrine braid-delta paleoenvironment. The four associations are: (1) lacustrine deposits, consisting dominantly of mudstones which were mostly deposited in the central and eastward basin area; (2) marginal lacustrine deposits, which were poorly developed and included fluvial mouth-bar, beach, and barrier deposits; (3) interdistributary deposits, consisting of a wide range of facies and sequences; (4) channel deposits, comprising the braided fluvial system sourced from the east.

Production in the Nipisi oil field is from the stratigraphically trapped Middle Devonian (Givetian) Gilwood Sandstone Member of the Watt Mountain Formation. The interbedding of the Gilwood Sandstone Member with Watt Mountain mudstones suggest that sedimentation occurred in cyclical paleoenvironmental conditions. Each of the Gilwood Sandstone Member depositional periods was attributed to tectonic activity associated with the Peace River Arch, while the Watt Mountain Formation mudstones were primarily deposited during relatively quiescent periods. The reservoir is present in six laterally continuous arkosic sandstone-dominated zones which vary in areal distribution. The distribution of each layer was controlled by the shape of the Muskeg trough and variations in the hydrologic conditions that existed during sedimentation.

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TABLE OF CONTENTS

Abstract

Acknowledgments

Table of Contents

List of Tables

List of Figures

CHAPTER 1 INTRODUCTION

1.1 Introduction 1

1.2 Study Area and Historical Development 1

1.3 Goals and Objectives 3

1.4 Previous Research 6

1.5 Nomenclature 8

1.6 Stratigraphy and General Geology 9

1.7 General Setting and Tectonic Framework 11

1.8 Division of the Watt Mountain Formation 16

CHAPTER 2 COMPOSITION OF WATT MOUNTAIN SEDIMENTS

2.1 Sandstones 17

2.2 Mudstones 18

2.2.1 Relationship of Composition and Colour 20

CHAPTER 3 FACIES DESCRIPTIONS AND INTERPRETATIONS

3.1 The Facies Concept 21

3.2 Facies Descriptions and Interpretations: 22

3.2.1 Facies 1 - Black Shale

Description: 22

Interpretations: 24

3.2.2 Facies 2 - Siltstone and Mudstone

Description: 24

Interpretations: 27

3.2.3 Facies 3 - Small-Scale Cross-Stratified Sandstone

Description: 33

Interpretations: 36

3.2.4 Facies 4 - Cross-Stratified Sandstone

Description: 37

Interpretations: 42

3.2.5 Facies 5 - Planar-Laminated Sandstone

Description: 44

Interpretations: 44

3.2.6 Facies 6 - Massive Sandstone

Description: 48

Interpretations: 48

3.2.7 Facies 7 - Interbedded Sandstone and Mudstone

Description: 51

Interpretations: 54

3.2.8 Facies 8 - Mixed Sand and Mud

Description: 55

Interpretations: 55

3.2.9 Limestones
Description: 58
Interpretations: 58

CHAPTER 4 WATT MOUNTAIN FAUNA AND ICHNOLOGY

4.1 Introduction 60
4.2 Watt Mountain Formation Fauna 60
4.3 Ichnology 62
4.4 Palynology 63

CHAPTER 5 VERTICAL FACIES ASSOCIATIONS AND INTERPRETATIONS:

5.1 Introduction 64
5.1.1 Facies Association 1 (Lacustrine Deposits)
Description: 64
Interpretations: 66
5.1.2 Facies Association 2 (Marginal Lacustrine Deposits)
Description: 68
Interpretations: 70
5.1.3 Facies Association 3 (Interdistributary Deposits)
Description: 72
Interpretations: 74
5.1.4 Facies Association 4 (Channel Deposits)
Description: 74
Interpretations: 76

5.2 Depositional Facies Model for the Watt Mountain Formation 79

CHAPTER 6 STRUCTURE

6.1 Regional and Local Structure 83
6.2 Origin of Muskeg Trough 86
6.3 Timing of Salt Solution Collapse 91

CHAPTER 7 DISTRIBUTION OF WATT MOUNTAIN SEDIMENTS

7.1 Introduction 102
7.2 Distribution of the Gilwood Sandstone Member 109
7.3 Distribution of Watt Mountain Formation Mudstones 110

CHAPTER 8 DEPOSITIONAL HISTORY OF THE WATT MOUNTAIN FM.

8.1 Introduction 111
8.2 Depositional History 111

CHAPTER 9 SUMMARY AND CONCLUSIONS 115
References 117
Appendix 126

LIST OF TABLES

Table 2.1 Average Mineralogy of Watt Mountain Sandstones 17

2.2 Mineralogy of Watt Mountain Mudstones From X-ray Diffraction Analysis 19

Table 7.1 Thickness of Mudstone Units Separating Gilwood Zones 110

LIST OF FIGURES

Figure 1.1 Study area location map illustrating the Gilwood Unit outline 2

1.2 Location of miscible flood stages 4

1.3 Map illustrating the wellbore and core control utilized in the study 5

1.4 Illustration of stratigraphic nomenclature used in this study together with dominant formation and member lithology 10

1.5 Middle Devonian tectonic and regional framework map of Alberta 12

1.6 Location of regional Gilwood Sandstone reservoirs 14

1.7 Illustration of Elk Point sediments onlapping the Peace River Arch 15

1.8 Six sandstone dominated zones within the Watt Mountain Fm. together with average reservoir properties 16

Figure 3.1 Facies 1 - Black Shale 22

3.2 Facies 2 - Mudstone

- A - D Typical green and red mudstone 26
- E - H Mudcracks and irregular shaped nodules 29
- I - L Fractures and calcareous clasts 31

3.3 Facies 3 - Small-scale cross-stratified sandstone 35

3.4 Facies 4 - Large-scale cross-stratified sandstone 39

3.5 Facies 5 - Planar-laminated sandstone 46

3.6 Facies 6 - Massive-sandstone 50

3.7 Facies 7 - Interbedded sandstone and mudstone 53

3.8 Facies 8 - Mixed sand and mud 57

3.9 Limestones 59

Figure 5.1 Facies Association 1 (Lacustrine Deposits) 65

5.2 Schematic illustration of the typical proximal and distal lacustrine deposits of Facies Association 1 67

5.3 Facies Association 2 (Marginal Lacustrine Deposits) 69

5.4 Schematic illustration of the typical marginal lacustrine deposits of Facies Association 2 71

5.5 Facies Association 3 (Interdistributary Deposits) 73

5.6 Schematic illustration of the typical interdistributary deposits of Facies Association 3 75

5.7 Facies Association 4 (Channel Deposits) 77

5.8 Schematic illustration of the typical channel deposits of Facies Association 4 78

5.9 Two end-member paleoenvironmental models for the Nipisi field area 81

Figure 6.1 Structural contours on the top of the Slave Point Formation 84

6.2 Structural contours on the top of the Watt Mountain Formation 85

6.3 Structural contours on the top of the Muskeg Formation 87

6.4 Restored Muskeg Formation structure map 88

6.5 Three-dimensional paleostructure diagram of the Muskeg Formation at the end of Watt Mountain time 89

6.6 Isopach map of the Watt Mountain Formation 90

6.7 Isopach map of the Muskeg Formation 92

6.8 Isopach map of salt within the Muskeg Formation 93

6.9 Contour map illustrating the estimated amount of collapse occurring by the end of Gilwood Zone 2 deposition 94

Figure 6.10 Contour map illustrating the estimated amount of collapse occurring by the end of Gilwood Zone 4 deposition 95
6.11 Contour map illustrating the estimated amount of collapse occurring by the end of Watt Mountain deposition 96
6.12 Reference map for cross-section C - C' illustrated in figures 6.13 to 6.16 97
6.13 Stratigraphic cross-section C - C' illustrating the correlation of the top of the Muskeg Formation before any post Muskeg collapse or deposition of Watt Mountain Formation sediments occurred 98
6.14 Stratigraphic cross-section C - C' illustrating the correlation of the Gilwood zones and the amount of post Muskeg collapse between wells by the end of Gilwood zone 2 deposition 99
6.15 Stratigraphic cross-section C - C' illustrating the correlation of the Gilwood zones and the amount of post Muskeg collapse between wells by the end of Gilwood zone 4 deposition 100
6.16 Stratigraphic cross-section C - C' illustrating the correlation of the Gilwood zones and the amount of post Muskeg collapse between wells by the end of Watt Mountain deposition 101

Figure 7.1 Isopach map of Gilwood Zone 1 103
7.2 Isopach map of Gilwood Zone 2 104
7.3 Isopach map of Gilwood Zone 3 105
7.4 Isopach map of Gilwood Zone 4 106
7.5 Isopach map of Gilwood Zone 5 107
7.6 Isopach map of Gilwood Zone 6 108

CHAPTER 1 INTRODUCTION

1.1 Introduction

Oil production in the Nipisi field is from the Middle Devonian (Givetian) Gilwood Sandstone Member of the Watt Mountain Formation. Nipisi is a stratigraphically trapped reservoir located on the eastward flank of the ancestral Peace River Arch. Extensive development of this reservoir has significantly increased the well control available for use in geological studies, and has provided an opportunity to reevaluate the complex distribution of Watt Mountain Formation sediments.

Successful future exploitation of the Nipisi field is dependent on the understanding of the areal distribution and continuity of the Gilwood Sandstone Member and the effect of structural controls. Therefore, the major goal of this thesis is to gain these understandings by developing a depositional history that explains Watt Mountain Formation sedimentation in the Nipisi field area.

1.2 Study Area and Historical Development

This study is of the Watt Mountain Formation in the unitized outline of Nipisi Gilwood Unit No. 1, located in Townships 78 to 81, Ranges 7 to 9W5M, approximately 273 km (170 miles) northwest of Edmonton (Fig. 1.1). Currently, the unitized area covers approximately 300 km^2, and contains 330 producing oil wells and 76 injectors.

The discovery of the Nipisi field in 1965 was due to a prompt northward extension of the Gilwood play that followed the discovery of the Mitsue Oil field in 1964. The Nipisi field was unitized (Nipisi Gilwood Unit No. 1) in 1969, to enable the implementation of a waterflood maintenance scheme. In 1978, the Nipisi field was evaluated for the possibility of a miscible flood development project, and in 1984, the

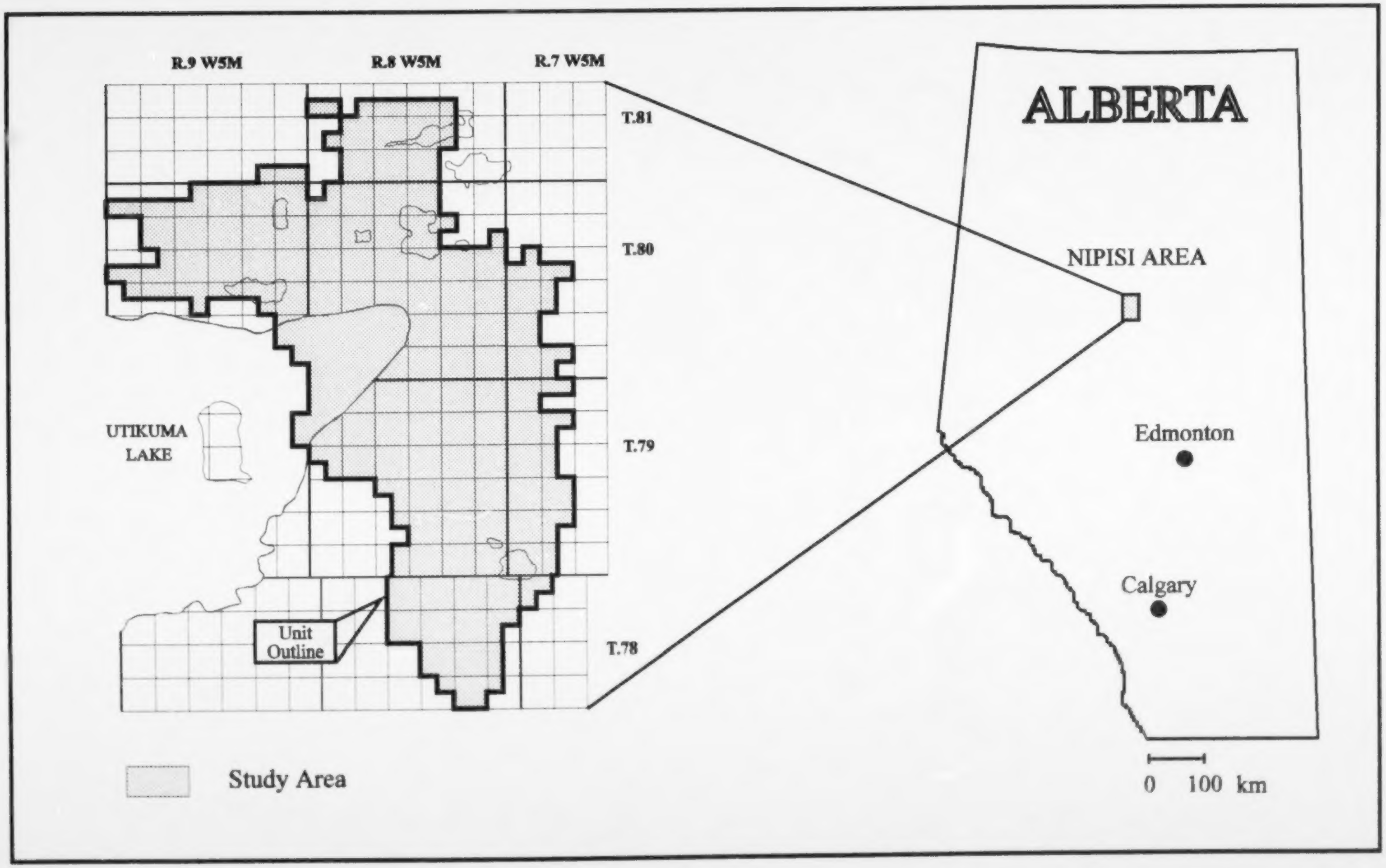


Figure 1.1 Study area location map illustrating the Gilwood Unit outline.

first miscible flood test area, named Stage I, was initiated to determine its effectiveness. Favorable production performance in Stage I prompted two further stages of miscible flood development: Stage II in 1986, and Stage III in 1988 (Fig. 1.2).

1.3 Goals and Objectives

The major goals of this thesis are to gain an understanding of the distribution and depositional nature of the Gilwood sandstones, and develop a geological model that will aid in the exploitation strategies of the Gilwood sandstone reservoir in the Nipisi field area.

The primary objectives were:

(1) to define sedimentary facies and vertical facies relationships in the Watt Mountain Formation;

(2) to develop a depositional facies model for the Watt Mountain Formation;

(3) to determine the influence and origin of the structural controls imposed on the Watt Mountain Formation;

(4) to map the distribution of the Gilwood Sandstone Member reservoir zones; and,

(5) to develop a depositional history of the Watt Mountain Formation.

The objectives of this study were accomplished by developing an extensive database using 52 core descriptions and 303 digitized mechanical well logs in the Nipisi field area (Fig. 1.3).

(1) Drill core descriptions

A total of fifty-two drill cores in the Nipisi field area were examined in Calgary at either the Energy Resource Conservation Board core research facility or the Shell

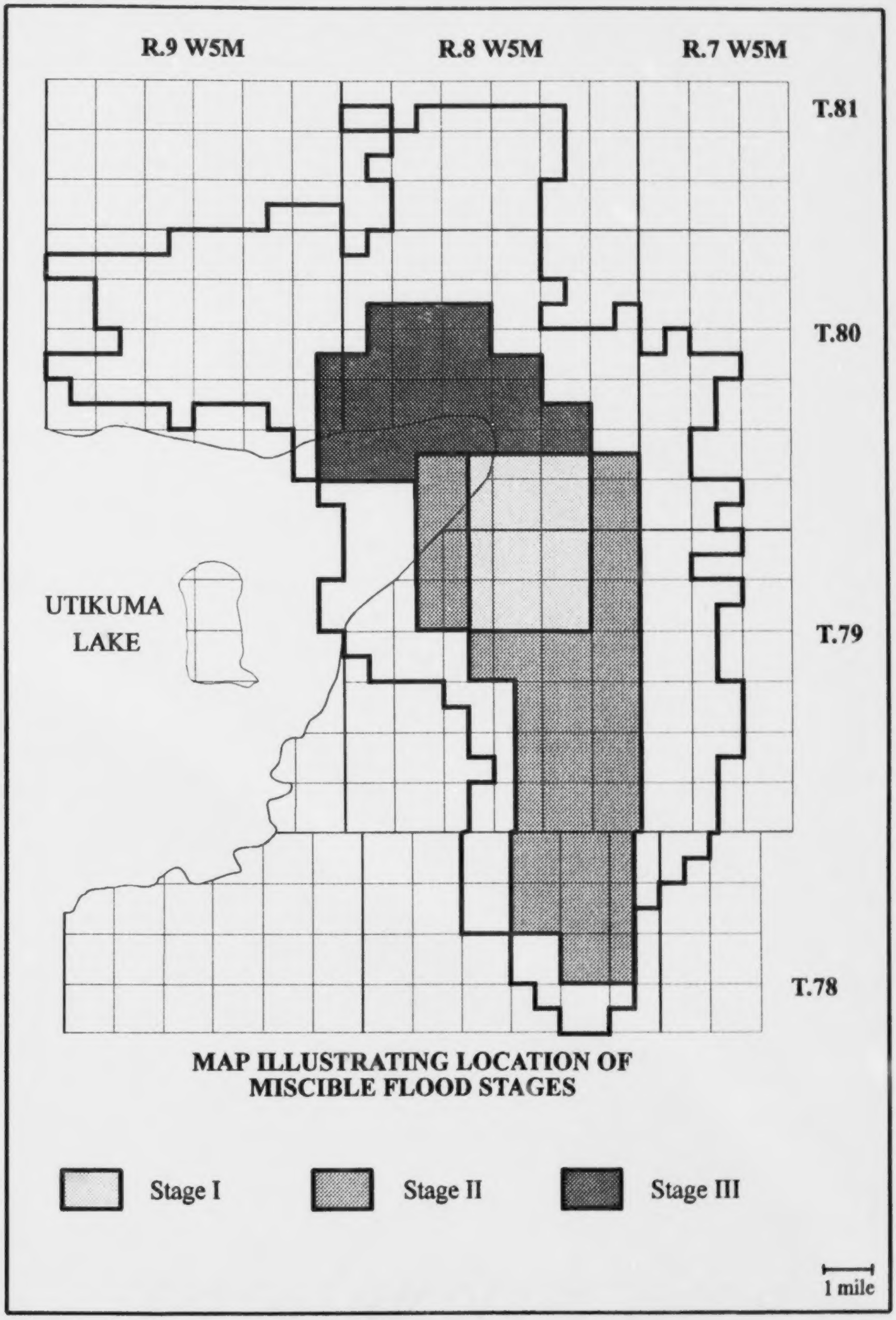


Figure 1.2 Location of miscible flood stages.

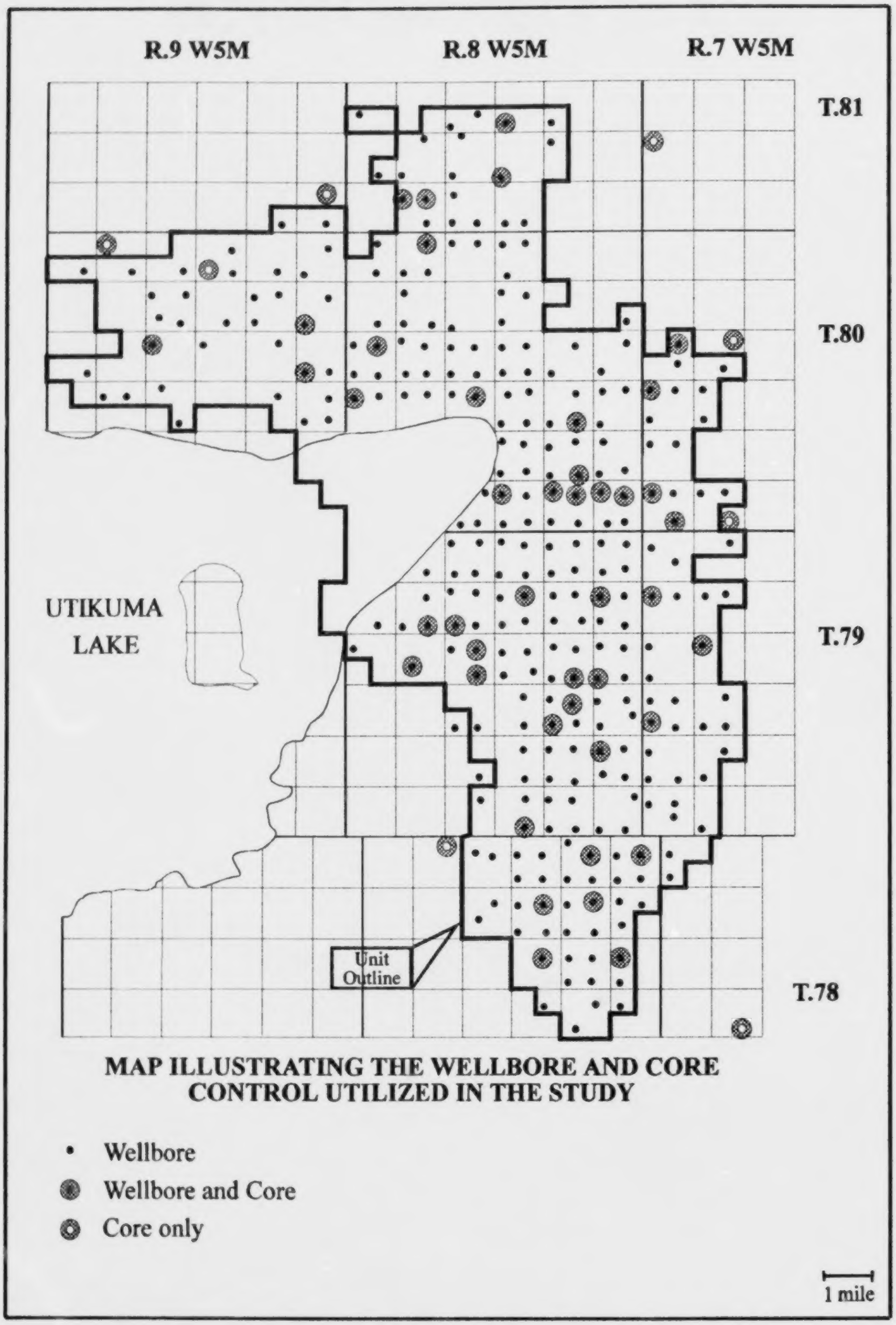


Figure 1.3 Map illustrating the wellbore and core control utilized in the study.

Canada core research center (Appendix A). The drill core descriptions include reference to:

(1) lithology,
(2) grain size and sorting characteristics,
(3) physical and biogenic sedimentary structures, and
(4) fauna content.

(2) Well logs

Digitized mechanical well logs from 303 wells were used to generate a subsurface database. The primary logs used included the Gamma Ray, Spontaneous Potential, Sonic, and Caliper. Before using these logs for correlations, they were normalized, expanded into a vertical scale of 1.15 m/cm, and calibrated with drill core data. The Spontaneous Potential and Gamma Ray logs proved to be the most useful; however, the Gamma Ray log was distorted in its reflection of shale content in the feldspathic sandstones. Once the database was generated, it was used to construct a collection of maps that illustrated the structural attitude of various paleosurfaces, and the three-dimensional distribution of the reservoir zones contained in the Watt Mountain Formation.

1.4 Previous Research

Research on the Watt Mountain Formation has been performed on both regional and local scales surrounding the ancestral Peace River Arch, and has provided published information on the petrology, sedimentology, and possible origins.

The Watt Mountain Formation was first named by Law (1955), and the Gilwood Sandstone as a member of the Watt Mountain Formation by Guthrie (1956). Guthrie

(1956) also referred to the Manning Wash on the north flank of the Peace River arch as a Gilwood equivalent. Greenwalt (1956) discussed the differentiation of the Granite Wash from the Manning or Gilwood, and Sikabonyi and Rodgers (1959) believed these two sands were time equivalents (Rottenfusser, 1974). A regional analysis of the Elk Point Group was presented by Suska (1963), who studied the Elk Point Group and Cambrian rocks of North-Central Alberta. The petrology and mineralogy of the Watt Mountain Formation in the Mitsue-Nipisi area have been studied by Kramers (1967), and Kramers and Lerbekmo (1967). Thachuk (1968) studied the sedimentology and depositional environments of the Watt Mountain Formation to determine the feasibility of waterflooding the Nipisi Oil field reservoir. He proposed that the sediments were deposited in a deltaic environment, and that they could be divided into 4 zones, each separated by a continuous shale bed. Shawa (1969) studied the Gilwood sandstone in the Nipisi field and proposed a deltaic origin for these sediments based on observations of textural analysis, paleocurrent analysis, sedimentary structures, and sandstone geometry. Nelson (1970) examined the cementing relationships in the Gilwood in the Mitsue oil field. Pugh (1972) discussed the relationship of the Gilwood Sandstone Member to both older coarse clastic detritus and to the Precambrian regolith. Jansa and Fischbuch (1974) discussed the evolution of Middle and Upper Devonian sediments in the Sturgeon - Mitsue area Alberta. Rottenfusser (1974), and Rottenfusser and Oliver (1977), described the petrology and depositional environments of the Watt Mountain Formation of Northern Alberta. Alcock and Benteau (1976) studied the physical characteristics and mineralogy of the Watt Mountain sediments and concluded that the Gilwood in the Nipisi field area was deposited in a fan-like deltaic system. They also divided the Nipisi field into three depositional realms: 1) alluvial plain, 2) delta plain and 3) delta front. Gibbs (1984) published an undergraduate thesis on the stratigraphy of the Gilwood in the Lovet Creek area, in Alberta. Horn *et al.* (1985) published an abstract that suggested the Middle Devonian Gilwood sandstones of the Watt Mountain Formation in the Utikuma-Nipisi field area was deposited in a fan-delta setting.

1.5 Nomenclature

McGehee (1949) was the first to use the name Elk Point Formation after describing rock units located near Elk Point in east-central Alberta. Belyea (1952) gave the Elk Point Formation group status, and Workman (1953) further divided the Elk Point into Upper and Lower portions. The Watt Mountain Formation is part of the Upper Elk Point Group and was defined by Law (1955):

> "This is the uppermost unit of the Elk Point and corresponds approximately with Workman's (1953) upper variable unit. It consists of a maximum of 155 feet of shale, siltstone, sandstone, arkose, limestone breccia, anhydrite and dolomite. The lithologic character of the unit is controlled to a large extent by the distance from the Peace River landmass." (p. 1951)

Law (1955) described the Watt Mountain Formation in the California Standard's Steen River No. 2-22-117-5W6 well, completed in April of 1953. In this well, the Watt Mountain Formation starts at a depth of 1356.9 m, is 18.5 m thick, and completely cored.

Guthrie (1956) designated the Gilwood Sandstone as a member of the Watt Mountain Formation in his discussion of the lithology and stratigraphy of the Gilwood in the Giroux Lake area, in Alberta. He defined and described the Gilwood Member in the Stanolind Giroux Lake well in 6-20-65-20W5. In the 6-20 well, the Gilwood Member is 10.4 m thick, starts at a depth of 3068.6 m, and has two cored intervals; 3070.7 to 3071.9 and 3072.2 to 3085.9 m. Guthrie (1956) refers to the Gilwood as "an outwash of arkosic sands over the surface of older formations wedging out around the Peace

River land mass." He restricted the term "Gilwood" to the outwash sand because in areas proximal to the Arch there was difficulty in distinguishing between the Granite Wash and the Gilwood sand. Many workers, beginning with Suska (1963), refer to the Gilwood Sandstone instead of the Gilwood Member. This more descriptive notation is used in the petroleum industry to such an extent that the Gilwood Member is now mainly called the Gilwood Sandstone Member. This thesis will concur with the industry usage of Gilwood Sandstone Member for the sandstones in the Watt Mountain Formation.

Rottenfusser (1974) discussed the nomenclature problem that existed before the early 1970's in naming the sandstones in the Watt Mountain Formation north and south of the Peace River Arch. These sandstones were found to be correlative, but the Peace River Arch was used as a barrier to create separate names. The sandstones in the Watt Mountain Formation were referred to as Manning Sand north of the Peace River Arch and Gilwood Sandstone south of the Arch. However, the term Manning Sand has since been dropped from active use.

1.6 Stratigraphy and General Geology

The Elk Point Group represents the Middle Devonian of the Nipisi field area (Fig. 1.4). Law (1955) divided the Upper Elk Point Group into three formations: Keg River at the base, Muskeg in the middle, and Watt Mountain at the top. The Keg River consists of a Lower Keg River open marine limestone unit and an Upper Keg River reefal limestone unit. The open marine limestones developed during a transgression that began at the beginning of Keg River deposition, and the development of carbonate build-ups in the Upper Keg River deposits occurred during a period of moderate shallowing (McCamis and Griffith, 1967). Open marine conditions during Keg River deposition were followed by restricted conditions and the deposition of the evaporitic Muskeg

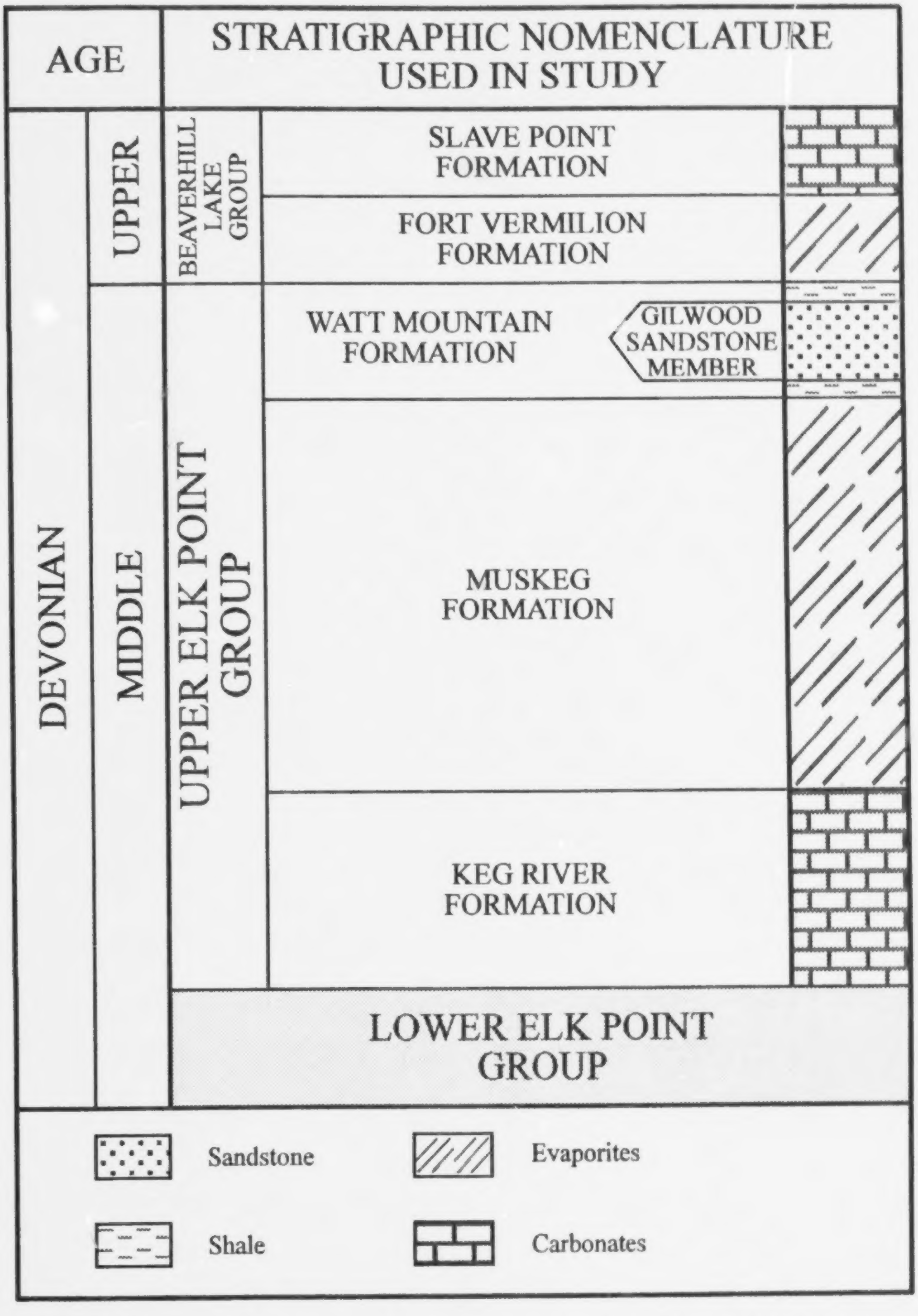


Figure 1.4 Stratigraphic nomenclature used in this study together with dominant formation and member lithology. Adapted from Bassett and Stout, 1967.

Formation. The Muskeg Formation consists of a basal salt deposit, and an upper unit of interbedded anhydrite and evaporitic dolomite. A regional uplift over the Peace River Arch and West Alberta Ridge resulted in the deposition of a regressive sandstone and shale sequence making up the Watt Mountain Formation (Bassett and Stout, 1967). The sandstones, defined as the Gilwood Member by Guthrie (1956), were deposited in cyclic sequences associated with tectonic activity associated with the Peace River Arch (Cant, 1988). After deposition of the Watt Mountain clastics, a standstill, or slight regression of the sea, resulted in the deposition of evaporites that make up the overlying Upper Devonian Fort Vermilion Formation. This slight regression was followed by a main transgressive phase of the late-middle Devonian, which deposited the limestones of the Slave Point Formation (Jansa and Fischbuch, 1974).

1.7 General Setting and Tectonic Framework

A regional framework for the deposition of Watt Mountain Formation is discussed here to place the study area in its appropriate paleogeographic setting. Devonian sediments of the Interior Plains and eastern Rocky Mountains were deposited on a slowly subsiding tectonic shelf bordering the Canadian Shield (Bassett and Stout, 1967). During the Middle Devonian, the Elk Point Sea covered most of Alberta, Saskatchewan, and Manitoba, and was partially separated from the sea over British Columbia by the exposed Western Alberta Ridge and Peace River High (Fig. 1.5) (Nelson, 1970). These two exposed highs strongly influenced the deposition of Middle Devonian sediments (Bassett and Stout, 1967).

The study area is located approximately 30 kilometers east of the eastern flank of the Peace River Arch, a feature that was tectonically active over a 500 m.y. period (O'Connell *et al.*, 1990). The proximity of the Nipisi field area to this activity was

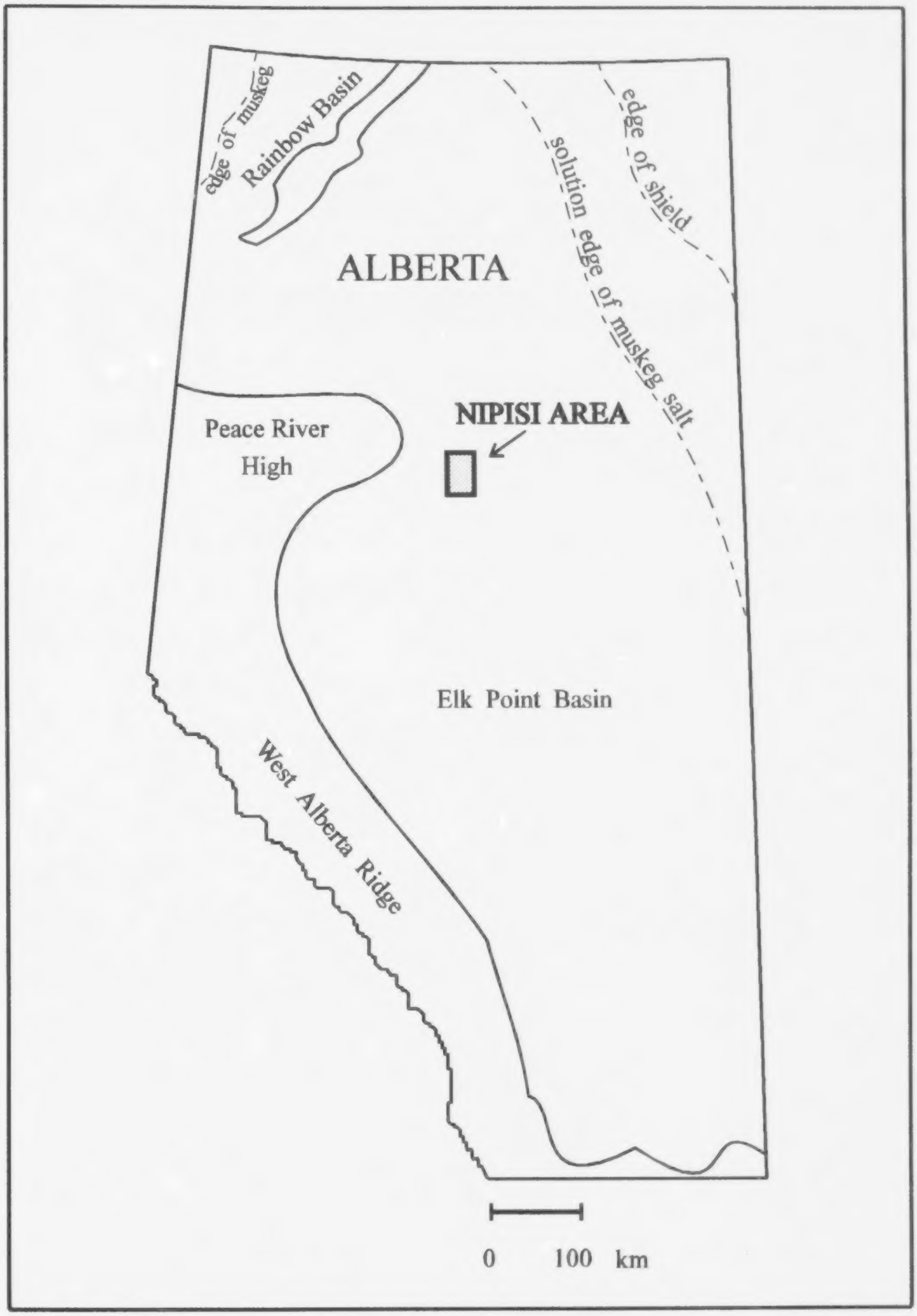


Figure 1.5 Middle Devonian tectonic and regional framework map of Alberta. Adapted from Bassett and Stout (1967).

undoubtedly a factor in the development of the present structural attitude of the Middle Devonian sediments in this area. The Peace River Arch is a major crustal structure that consists of uplifted Precambrian rock, and is associated with many faults that cut the overlying Devonian, Mississippian, and Pennsylvanian sediments (Cant, 1988).

The exact timing of the Arch's initial phase of uplift is uncertain, but evidence of sandy Middle Cambrian units terminating against the Arch suggests that the initiation of the Peace River Arch had occurred by the Mid-Cambrian (Pugh, 1972; Cant, 1988). Silurian sediments preserved to the north, northwest, and southwest of the Peace River Arch indicates that it was emergent at this time (Norford, 1990). By the Middle to Late Devonian the first episode of normal faulting occurred (Cant, 1988). These faults generated local topographical relief which enhanced the erosional activity on the Peace River Arch. This erosion was the source of the clastic debris that accumulated at Nipisi. Cant (1988) suggested that the interbedding of these clastics with other Elk Point Group sediments indicates that several distinct episodes of tectonism occurred during this time. However, Basset and Stout (1967) and Geldsetzer (1990) believe that the development of the clastics occurred during a major regressive hiatus in the basin.

The Arch persisted as a positive tectonic feature until the slow transgression that started during Upper Devonian time gradually transgressed the elevated areas (Sikabonyi and Rodgers, 1959). Besides gradual eustatic sea level rise, the burial of the Arch may also have also occurred through subsidence or a combination of the two (O'Connell *et al.*, 1990). Although the Arch was no longer emergent, faulting and subsidence continued throughout the Mississippian and Pennsylvanian, and it was not until the end of Pennsylvanian-Permian deposition that major structures became inactive (Cant, 1988). Because the Arch was the source of Gilwood clastics, stratigraphic and structurally trapped Gilwood reservoirs occur in close proximity to it (Figs. 1.6 and 1.7).

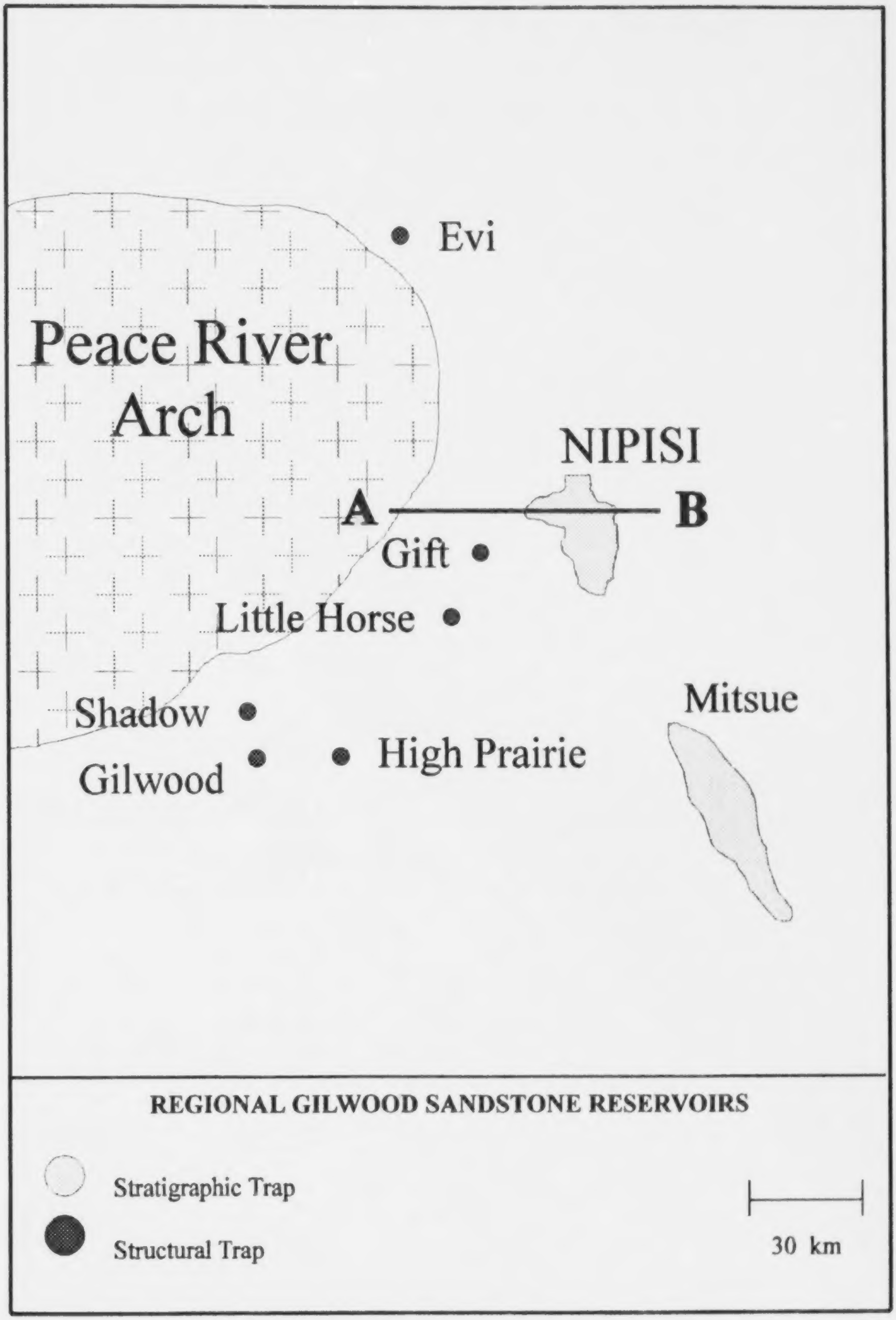


Figure 1.6 Location of regional Gilwood Sandstone reservoirs.

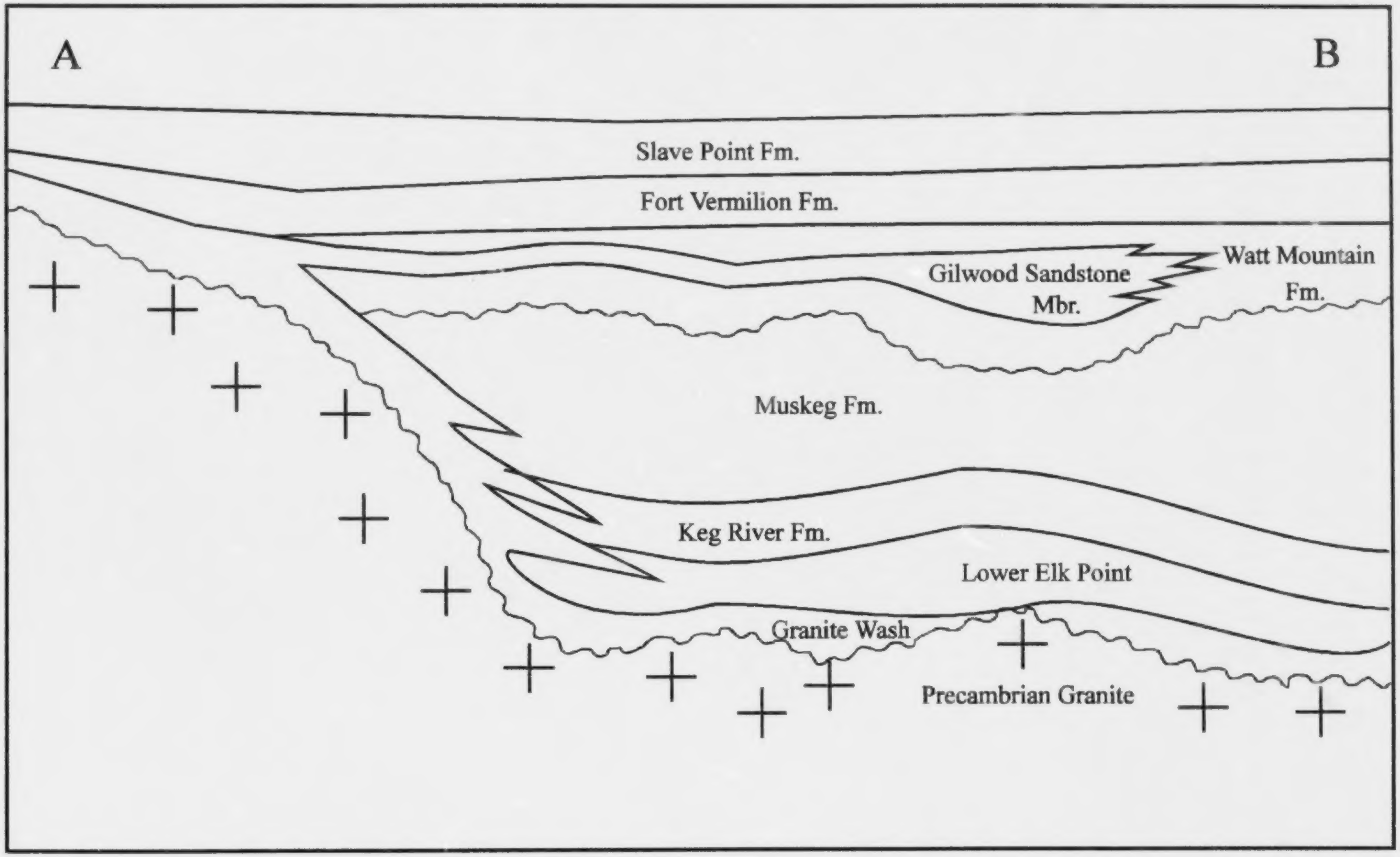


Figure 1.7 Schematic cross section A-B (referenced in Fig. 1.6) illustrating Elk Point sediments onlapping the Peace River Arch in the Nipisi area. Adapted from Shawa (1969).

1.8 Division of the Watt Mountain Formation

With limited well control, Thachuk (1968) divided the Watt Mountain Formation into 4 zones, each containing one or more sandstone beds. However, the present study shows that it is possible to divide the sandstone-dominated units into 6 discrete correlatable zones (Figure 1.8).

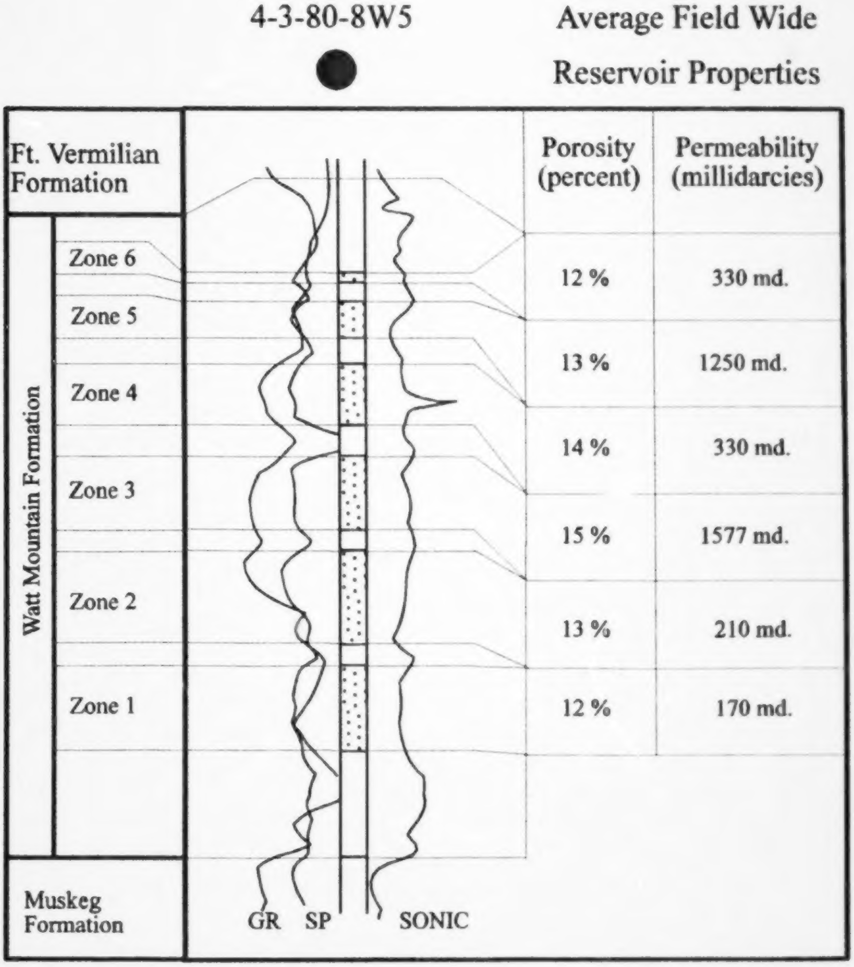


Figure 1.8 Illustration of the six Gilwood Sandstone Member zones of the Watt Mountain Formation together with average reservoir properties.

CHAPTER 2 COMPOSITION OF WATT MOUNTAIN SEDIMENTS

2.1 Sandstones

The average composition of the Gilwood Sandstone Member in the Nipisi field area has been documented by Kramers and Lerbekmo (1967), Thachuk (1967), and Alcock and Benteau (1976). Because of this writer's division of the Gilwood into 6 correlatable zones, 2 thin sections from each zone were evaluated to determine if any of the zones had a distinct mineralogical difference. The results showed that all zones had similar mineralogic characteristics, suggesting a similar source for all episodes of clastic deposition in the Nipisi Field area (Table 2.1).

Mineral	Average %
Quartz	57.5
Feldspars	24.8
Carbonate	4.1
Anhydrite	6.8
Accessories	<1.0

Table 2.1 Average Mineralogy of Watt Mountain Sandstones based on all published compositional data.

On the basis of their compositional range, the Gilwood sandstones are classified as arkoses and subarkoses according to the mineralogic classification system for sandstones used by McBride (1963). Accessory minerals and rock fragments generally make up less than 1 percent of the sandstones, and can include detrital biotite, chert, igneous-metamorphic rock fragments, and shale fragments (Kramers and Lerbekmo, 1967).

2.2 Mudstones

The mineralogy of the Watt Mountain Formation mudstones was analyzed using x-ray diffraction techniques at Shell Canada's Research Centre in Calgary, Alberta. Eight samples from four wells were processed for bulk analysis, and one sample was further analyzed to separate the clay fraction (Table 2).

Clays in the mudstone samples included illite, kaolinite, and chlorite. Illite was the main clay component in all 8 samples, averaging 36%; kaolinite and chlorite were clearly subordinate. This ranking is consistent with the findings of Kramers and Lerbekmo (1967), Rottenfusser (1974), and Alcock and Benteau (1976). The large amounts of illite reflects the abundance of potassium-rich minerals found in the Gilwood sands. Potassium rich clays like illite are generated at the expense of potassium rich minerals and potassium poor clays (Retallack, 1990).

Alcock and Benteau (1976) analyzed samples from three wells in the Nipisi area and reported that a high dolomite content compared to calcite was a characteristic feature of Watt Mountain Formation mudstones in the Nipisi area. In this thesis, half the processed samples detected only <1% dolomite, and calcite was found in amounts up to 13%. The combined results reflect a broader view of carbonate content in the Nipisi Field, a view that corresponds with Watt Mountain Formation mudstone compositional values in other field areas. Rottenfusser (1974) analyzed Watt Mountain Formation mudstones north of the Peace River Arch, and proved a relationship between higher proportions of calcite and proximity to freshwater limestone deposits. Thinner limestones with a similar appearance were found in the Nipisi area, and may also be the source of local increases in carbonate content. Quartz and potassium feldspar was detected in all samples, and their abundance is directly related to the sand and silt content of the mudstones.

Location 12-24-78-08W5

Depth	Qtz	Plag	K-feld	Calc	Dol	Anhy	Sid	Pyr	Kaol	Ill	Chl
5676 ft	17	-	4	-	20	-	-	-	7	52	-
5686 ft	25	-	4	1	41	2	-	-	4	23	-

Location 10-27-78-08W5

Depth	Qtz	Plag	K-feld	Calc	Dol	Anhy	Sid	Pyr	Kaol	Ill	Chl
5699.5 ft	10	-	5	12	-	-	<1	-	-	63	10
5699.6 ft	7	-	4	13	-	-	<1	-	-	67	9

Location 12-20-79-08W5

Depth	Qtz	Plag	K-feld	Calc	Dol	Anhy	Sid	Pyr	Kaol	Ill	Chl
5543.8 ft	36	2	7	-	14	3	-	2	11	24	-
5564.2 ft	30	-	28	10	<1	3	-	2	1	25	-

Location 12-21-80-09W5

Depth	Qtz	Plag	K-feld	Calc	Dol	Anhy	Sid	Pyr	Kaol	Ill	Chl
5636 ft	35	-	51	9	<1	2	<1	-	-	2	-
5647 ft	30	-	28	10	<1	3	-	2	1	25	-

Table 2.2 Mineralogy of Watt Mountain Formation Mudstones From X-ray Diffraction Analysis.

2.2.1 Relationship of Composition and Colour

Based on the G.S.A. colour chart, the Watt Mountain Formation mudstones are present in solid and variegated varieties of medium gray (N 5), olive-gray (5 Y 4/1), pale-green (10 G 6/2), grayish-green (5 G 5/2), dark reddish-brown (10 R 3/4), dusky-red (5 Y 3/4), and black. Although there is a coloured variety of mudstones, at all sandstone- mudstone contacts the colour was always green. An attempt was made to determine if the green colouration was a result of mineralogical differences.

Four pairs of mudstone samples, one red and one green, were taken from the same well location and analyzed with x-ray diffraction techniques to determine the mineralogy. In the 10-27 well, the possible error of sampling from different types of mudstones was decreased by taking samples of each colour 4 cm apart. The data provided no evidence to suggest that the colour difference was caused by differences in mineralogy (Table 2.2). Kramers and Lerbekmo (1967) also found no correlation between total iron content and colour of the mudstones in Watt Mountain Formation mudstone samples in the Mitsue field. They concluded that colour differences were caused by different oxidation states of the iron present. The theory that colour is independent of total iron content and dependent on Fe^{3+}/Fe^{2+} has been demonstrated by workers including Tomlinson (1916), Pettijohn (1975), and McBride (1974). Potter *et al.* (1980) concluded from Van Houten's (1973) work that the colour in sediments can be changed so easily that it is usually of depositional or diagenetic origin rather than detrital. The exact cause of the green colouration occurring at all mudstones-sandstone contacts is unknown, but because of their similar mineralogy and the presence of green reaction zones at all sandstone-mudstone contacts, it is likely that the green colouration has a diagenetic origin.

CHAPTER 3 FACIES DESCRIPTIONS AND INTERPRETATIONS

3.1 The Facies Concept

Although the word facies is seen regularly in published work, it has been used in the wrong context so often that its usefulness as a geologic term has been hampered. Conceptual problems of the term have centered on its misuse as a purely descriptive term, and its use in branches of scientific work other than sedimentary geology.

Facies is a Latin word derived from *facia* or *facies* meaning the external appearance or look of something (Teichert, 1958; Walker, 1984). It was initially introduced into the geologic literature by Nicolaus Steno in 1669 to signify the entire aspect of the earth's surface during an interval of geologic time. Modern scientific usage of the facies concept was derived from comparative stratigraphic studies done in 1838 by Swiss geologist, Amand Gressly (Teichert, 1958). Although Gressly is regarded as the founder of the facies concept, another geologist, Prevost, can rightly be regarded as a co-founder (Teichert, 1958). Prevost independently deduced similar principles to that of Gressly at around the same time, but by using only simple reasoning and observation (Teichert, 1958). A translation of Gressly's definition was given by Teichert (1958), and reads as follows:

> "To begin with, two principal facts characterize the sum total of the modifications which I call facies or aspects of a stratigraphical unit: one is that certain lithological aspect of a stratigraphic unit is linked everywhere with the same paleontological assemblage; the other is that from such an assemblage fossil genera and species common in other facies are invariably excluded."

The core of Gressly's 1838 facies concept was the interdependence of lithological and paleontological information. Scientists commonly separate the lithological and paleontological aspects of by using terms like "lithofacies" and "biofacies"; however, these concepts are intermixed (Middleton, 1978). Gressly also implied that facies were to be areally unrestricted. For example, Middleton (1978) pointed out an exemplary example of the use of facies by De Raaf *et al.* (1965), who subdivided a group of three formations into a cyclic repetition of facies distinguished by "lithological, structural and organic aspects detectable in the field."

The term "facies" is a purely descriptive one representing the sum of primary lithological and paleontological properties of a stratigraphic unit, and is to be used in an areally unrestricted sense. Individual facies are important for providing insight toward the hydrodynamic and ecological conditions at time of deposition. The most common misuse of the facies concept is the application of facies to assumed environmental conditions rather than to reconstructing environments by means of the study of facies (Middleton, 1978).

3.2 Facies Descriptions and Interpretations

Lithological, sedimentological, and paleontological features were used to define eight distinct facies in the Watt Mountain Formation in the Nipisi field area. The following is a description of those eight facies and the interpreted paleohydrodynamic conditions that generated them. The significance of the paleontological features will be discussed more thoroughly in Chapter 4.

3.2.1 Facies 1 - Black Shale

Description:

Facies 1 is a distinctive black shale that ranges from 0.03 - 0.45 m in thickness (Fig 3.1). The shale contains thin (<1 mm) horizontal laminations and was typically very

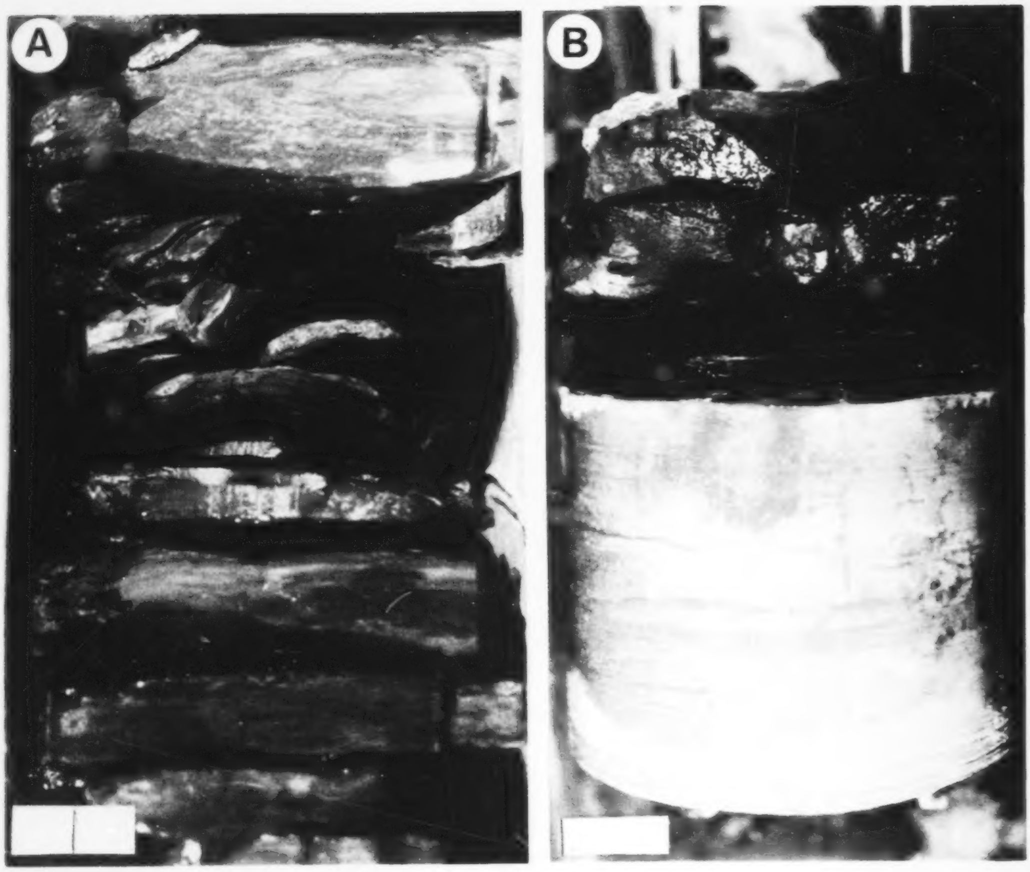


Figure 3.1 Facies 1 (Black Shale Facies)

A) Typical black fissile shale of facies 1. Note the contact with an overlying grayish green mudstone 2.5 cm from top of core. The photograph is from 4-25-80-9W5, 1695.8 m. Scale bar is 2 cm.

B) Contact of black shale with underlying anhydritic shale of the Muskeg Formation. The photograph is from 4-18-79-7W5, 1717.0 m. Scale bar is 2 cm.

fissile. It was located at or near the basal contact of the Watt Mountain Formation where it predominantly occurs as a single bed, but occasionally it was interbedded with a tan to variegated-in-colour anhydritic shale. Both upper and lower bedding contacts are always sharp and planar. No biogenic sedimentary structures were observed in the black shales; however, body fossils identified as *Lingula* occur in moderate amounts.

Interpretations:

These laminated black shales are vertically accreted deposits reflecting the process of suspension settling in a very low energy environment. The lack of silt or sand-sized particles suggests that the energy levels remained low throughout deposition. In order for these shales to develop their black colouration they must contain >3% organic carbon (Potter *et al.*, 1980). Because organic matter is best preserved in anaerobic conditions, black shales are mostly interpreted to represent deposition at water depths greater than 50 meters (McCollum, 1988). However, Selley (1985) demonstrated that stratification of the water column and development of anoxic condition can occur in shallow water environments.

This facies has a distinct lack of diverse benthic fauna and biogenic structures, suggesting that ecological conditions were largely unfavorable for the survival of most organisms.

3.2.2 Facies 2 - Mudstone

Description:

Facies 2 is composed of mudstones that are commonly silty and sandy, and exist in a variety of colours including solid and variegated shades of grayish green, dusky red, and rarely gray (Fig. 3.2 (A-D)). Average units are 1.5 m thick, and thicknesses range

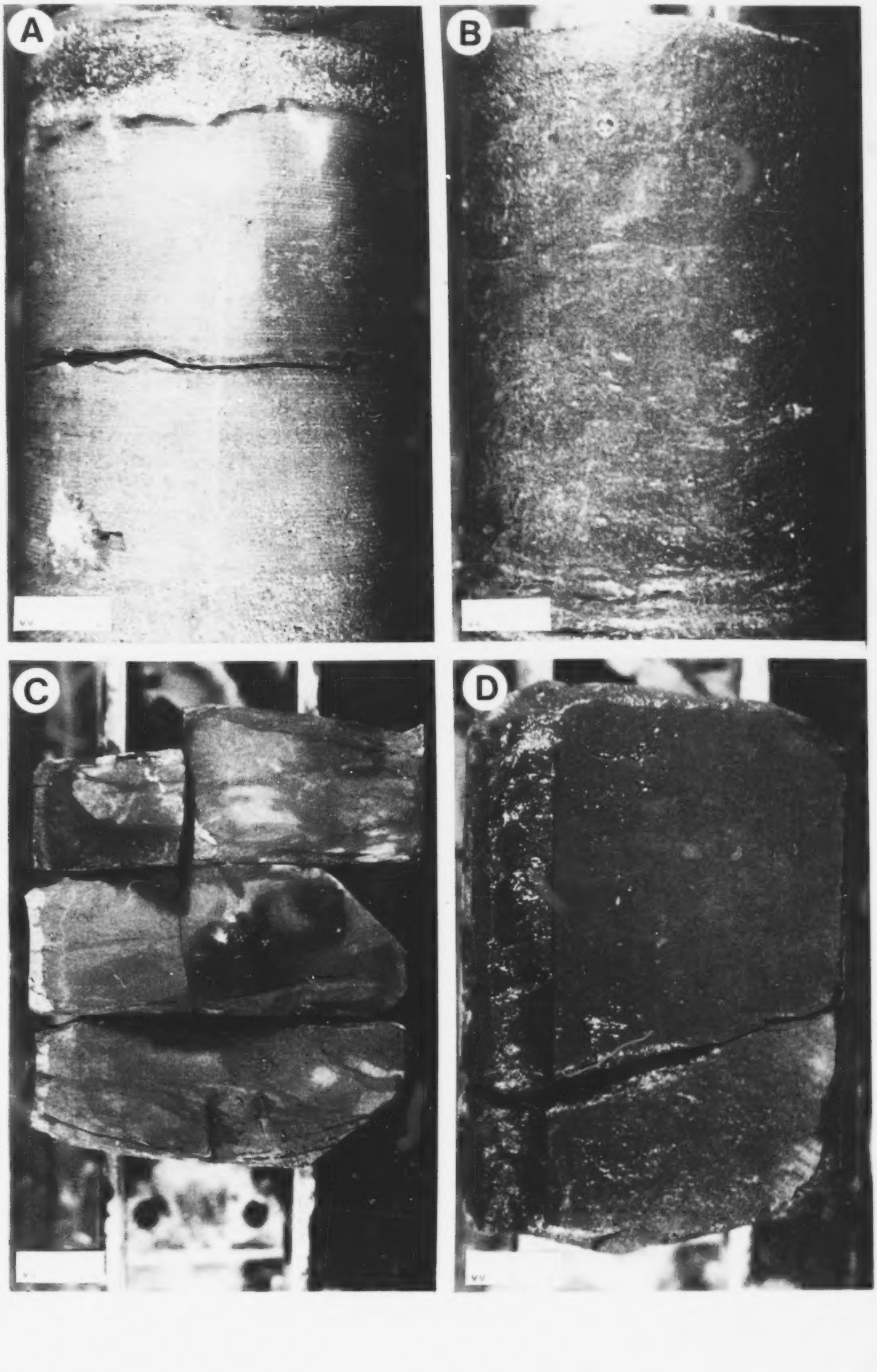
Figure 3.2 (A-D) Facies 2 (Typical Green and Red Mudstone)

A) Pale green mudstone with scattered fine to coarse sand sized grains at the base, and a thin (1.5 cm) sandstone bed near the top of core. The photograph is from a mudstone unit below Gilwood zone 2 in 4-18-79-7W5, 1715.6 m. Scale bar is 2 cm.

B) Dusky green silty mudstone with sparse sand size grains. The photograph is from the uppermost mudstone unit in the Watt Mountain Formation in 10-21-79-8W5, 1739.2 m. Scale bar is 2 cm.

C) Dark reddish brown blocky mudstone. The photograph is from a mudstone unit below Gilwood zone 2 in 10-21-79-8W5, 1744.0 m. Scale bar is 2 cm.

D) Dark reddish brown blocky mudstone. The photograph is from a mudstone unit below Gilwood zone 5 in 4-25-80-9W5, 1718.4 m. Scale bar is 2 cm.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from a few cm to 5.2 m. Single mudstone beds are displayed in units of alternating colours of red and green, separated by either sharp or gradational contacts. Mudstone beds are typically bounded above and below by sandstones. Lower mudstone-sandstone contacts can be sharp or gradational, while upper contacts are always sharp and occasionally scoured. Scattered sandstone grains ranging from very fine to very coarse are present in the majority of mudstone beds. These scattered grains may exist throughout the facies or in localized areas, and are mostly found near the upper and lower contacts.

Slickensided surfaces are present in these mudstones. They are best viewed on the plane view of a vertical core where they can either cover the entire surface area, or are smaller (<1 cm), diffuse, and randomly arranged. Associated with the small slickensides is a crumbly texture, as opposed to a typical blocky texture of mudstones without slickensides.

The mudstones occasionally contain polygonal and irregular shaped cracks, which were most often filled with a fine-grained sandstone (Fig. 3.2 (E-F)). Sand filled cracks in red mudstones exhibit a thin (1-3 mm) green coloured zone at the edges of the crack that enhanced its visibility. Some mudstones contain nodules that are typically brecciated, but whole forms up to 2.5 cm in diameter were also observed (Fig. 3.2 (G-H)). The mudstones of this facies also contain very rare sand filled vertical fractures (Fig. 3.2 (J)).

In the mudstones are rare, scattered, and randomly oriented calcareous intraclasts and calcareous zones. They are either spherical, elongate, or irregular in shape, and have maximum diameters ranging from 0.2 to 2.5 cm (Fig. 3.2 (K)).

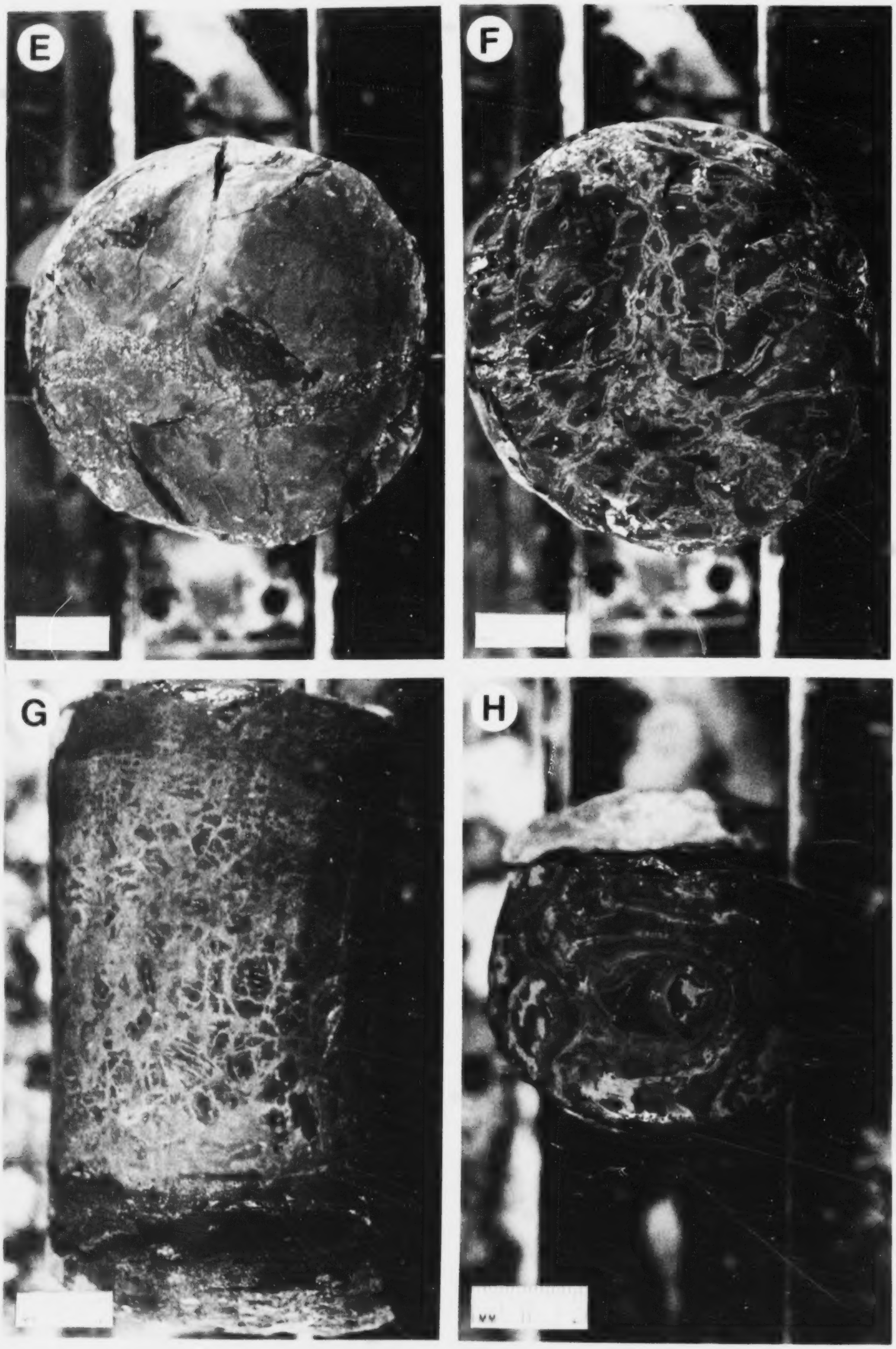
Figure 3.2 (E-H) Facies 2 (Mudcracks and Irregular Shaped Nodules)

E) Sand filled polygonal shaped mud cracks in a variegated dark reddish brown and pale green mudstone. The photograph is a bedding plane view of a mudstone unit below Gilwood zone 2 in 4-18-79-7W5, 1715.9 m. Scale bar is 2 cm.

F) Small irregular shaped mudcracks filled with a very-fine grained sand, in a variegated dark reddish brown and pale green mudstone. Note how the visibility of the mudcracks is enhanced by the presence of a thin (1 mm) pale green reaction zone. The photograph is a bedding plane view of a mudstone unit below Gilwood zone 2 in 4-18-79-7W5, 1715.9 m. Scale bar is 2 cm.

G) Brecciated appearance of a dark reddish brown mudstone. Note an original spherical shape (S) associated with the brecciated area. The photograph is from a mudstone unit just above Gilwood zone 1 in 10-19-80-7W5, 1691.1 m. Scale bar is 2 cm.

H) A septarian concretion developed in a dark reddish brown mudstone. The photograph is from a mudstone unit above Gilwood zone 1 in 10-19-80-7W5, 1689.5 m. Scale bar is 2 cm.


E
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H

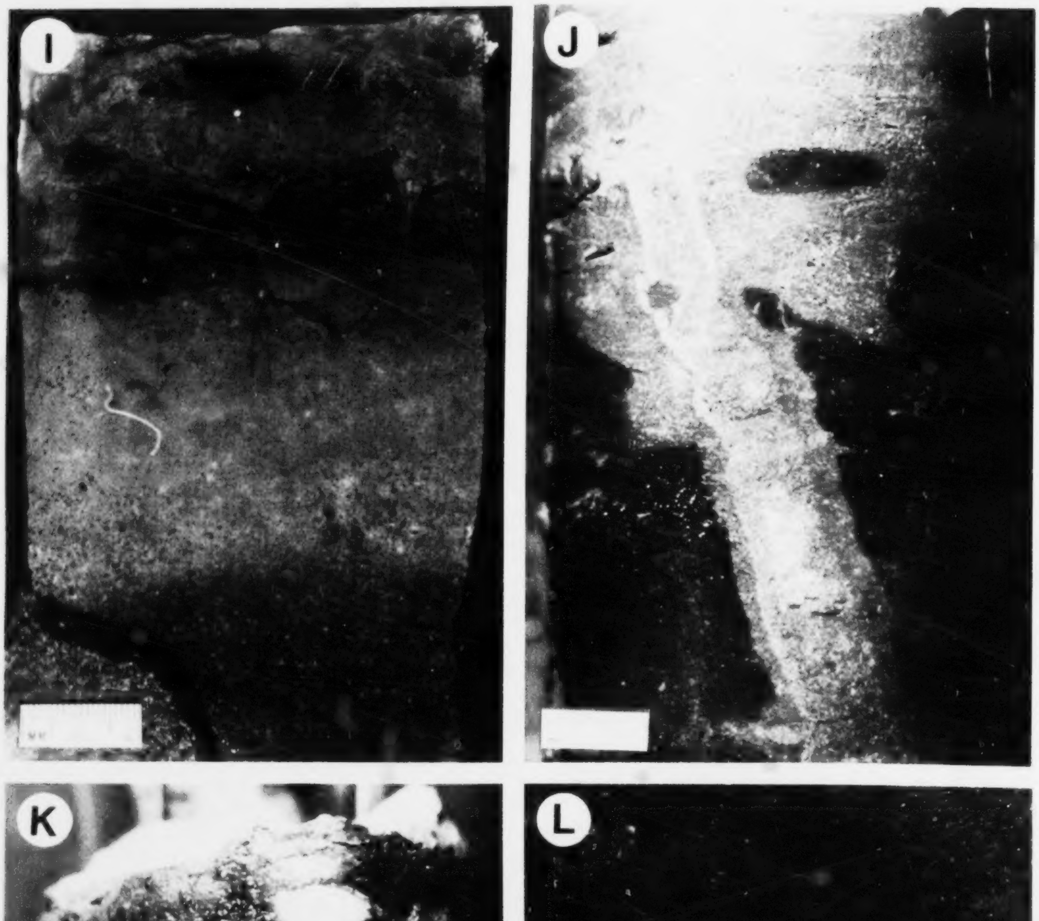
Figure 3.2 (I-L) Facies 2 (Fractures and Calcareous Clasts)

I) Vertical micro-desiccation cracks occurring across a gradational contact separating a lower pale green mudstone and an upper dark reddish brown mudstone. The photograph is from a mudstone unit directly above the upper contact of Gilwood zone 2 in 4-18-79-7W5, 1724.7 m. Scale bar is 2 cm.

J) Large sand-filled fracture passing through a dark reddish brown and pale green mudstone. This fracture initiated from a sandstone bed located 8 cm below bottom of photograph. Note the pale green alteration zone at the edge of the fracture. The photograph is from a mudstone unit above Gilwood zone 1 in 10-21-79-8W5, 1744.8 m. Scale bar is 2 cm.

K) Variegated dark reddish brown and grayish green mudstone with scattered calcareous clasts. The photograph is from a mudstone unit just above Gilwood zone 4 in 10-21-79-8W5, 1734.8 m. Scale bar is 2 cm.

L) Mottled grayish green and dark reddish brown silty mudstone with scattered fine- to coarse-grain sand. The photograph is from a silty mudstone unit above Gilwood zone 2 in 6-20-79-8W5, 1743.3 m. Scale bar is 2 cm.


I
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K
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Interpretations:

The mudstones are vertically accreted deposits interpreted to reflect deposition in a low energy setting by suspension fallout. Suspension fallout is associated with either temporally or spatially decreasing suspension transport (Harms *et al.*, 1982). The presence of scattered silty and sandy zones in the mudstone suggests that the hydrodynamic conditions of the system fluctuated, and were occasionally increased to levels that allowed the transportation of silt and sand sized particles. Scattered coarse grains may also indicate a proximity to relatively strong currents (Harms *et al.*, 1982). Because the silt and sand grains remained scattered and were not shaped into thin beds, current velocities remained low enough to prevent the movement of grains on the bed after they settled.

Accessory features in this facies indicate the existence of post-depositional alteration of the mudstones. The red coloured mudstones suggest that post-depositional oxidation occurred since almost no modern streams transport truly red alluvium (Van Houten, 1973). Oxidation reactions mainly occur in well drained soils, but may also occur in coarse-grained shallowly buried materials circulated by oxygenated water (Retallack, 1990). The persistence of green mudstones at all sandstone-mudstone contacts is a diagenetic feature (McBride, 1974), clearly shown when green coloured mudstones transect red mudstone bedding.

The two sizes of slickensides represent two distinct origins. Slickensides covering the entire surface area of core are interpreted to represent movement along a possible fault plane, while the smaller types are interpreted to be stress cutans. Stress cutans are indicated by randomly arranged diffuse slickensides (Retallack, 1990). These stress cutans can be formed in clayey soils where peds (aggregates of soil) are repeatedly heaved past one another by swell-shrink during wetting and drying episodes, or they may be formed after burial when compaction also causes peds to be crushed against each other (Smith, 1990; Retallack, 1990).

The mud cracks are interpreted to be formed due to shrinkage or desiccation of muds during subaerial exposure; however, desiccation can occur in both subaerial and subaqueous environments. Desiccation resulting in the development of polygonal or rectilinear networks of cracks occurs when interstitial waters are removed, causing mineral grains to become densely aggregated (Potter *et al.*, 1980). Mudcracks have been reported to occur in both horizontal surfaces or on hill slopes as steep as 38 degrees (Plummer and Gostin, 1981). The complex nodular forms of the red mudstone are interpreted to be septarian nodules. Fluctuations of oxygenation in paleosols may induce septarian cracking, a process which results in brecciation of the nodules. (Retallack, 1990).

Similar descriptions of calcareous nodules have been described under various terms, including concretion, nodule, cornstone, and kankar. The formation of these nodules is interpreted by most workers to be during early diagenesis above the water table, and some have related them to soil-forming processes (McBride, 1974). Soil nodules and concretions are commonly formed in dry, well drained soils, and reflect the availability of oxygen at the time of formation (Retallack, 1990).

3.2.3 Facies 3 - Small-Scale Cross-Stratified Sandstone

Description:

Facies 3 is characterized by thin beds (<8 cm) of cross-laminated sandstone (Fig. 3.3) that is commonly muddy and chiefly fine- to very fine-grained. Cross-stratification is dominated by asymmetrical tabular forms, but more complex slightly symmetrical

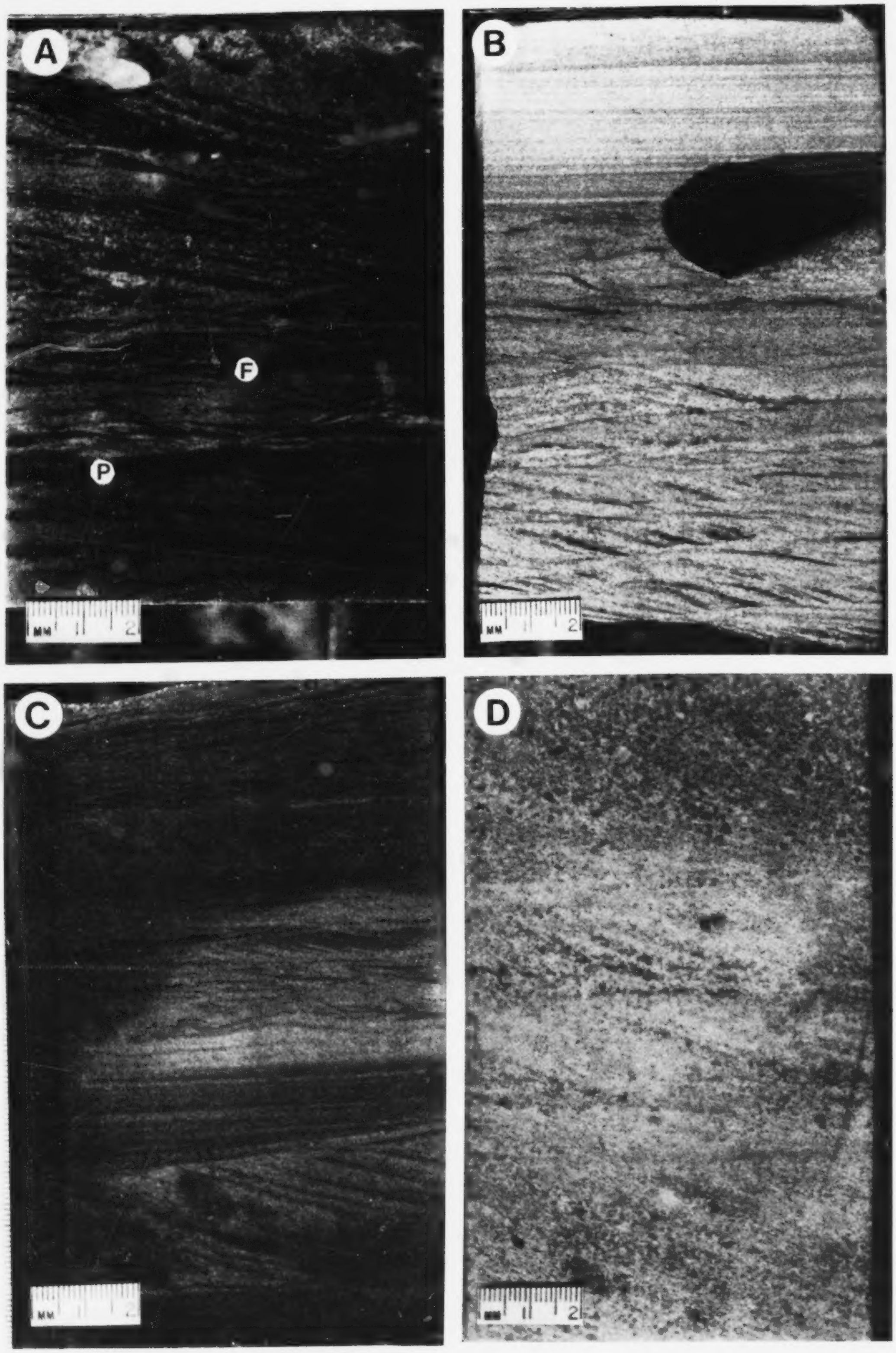
Figure 3.3 Facies 3 (Small-Scale Cross-Stratified Sandstone)

A) Fine-grained, small-scale cross-stratified sandstone with current and combined flow ripples. Note the near planar grayish green mud parting (p) and the mud flasers (f). The photograph is from the upper part of a finning upward sandstone within Gilwood zone 1 in 1-32-78-8W5, 1729.1 m. Scale bar is 2 cm.

B) Fine-grained, small-scale cross-stratified sandstone illustrating climbing ripples formed in 1.5 cm sets. Note the planar laminated sandstone overlying the small-scale cross-stratified sandstone. The photograph is from the lower portion of a coarsening upward sequence developed in Gilwood zone 2 in 4-18-79-7W5, 1732.8 m. Scale bar is 2 cm.

C) Photograph illustrating the close relationship between fine-grained small-scale cross-stratified sandstones and planar laminated sandstones. The photograph is from a lower part of Gilwood zone 3 in 12-25-79-8W5, 1719.8 m. Scale bar is 2 cm.

D) Medium grained, small-scale cross-stratified sandstone. The photograph is from Gilwood zone 1 in 12-30-79-7W5, 1711.7 m. Scale bar is 2 cm.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cross-stratification can be present. The asymmetrical tabular-shaped cross stratification is internally composed of high-angle (>20°) cross beds with set thicknesses of <3 cm, and cosets ranging up to a maximum of 8 cm. The shape of the lower bounding surface varies from straight to curved, and can be inclined up to an angle of 10°. The upper bounding surface is similar to the lower except gradational forms may also exist. This facies is not a very common one. It is usually associated with the planar laminated sandstone facies, and is dominantly located in the upper beds of fining upward sequences which are initiated by large-scale cross-bedded sandstones.

Thin (1 mm to 5 mm) mud drapes and discontinuous mud flasers occur in this facies. They are present as laminations in the sets and cosets of the small-scale cross-laminated sandstone. The drapes have lower contacts that are sharply conformable to the lower bounding surface, and upper contacts that are either sharp or scoured. Convolute bedding in the form of slumping occurs rarely, and it may produce a near vertical appearance to the fabric of sediment. Angular mudstone intraclasts ranging in size from 0.2 to 3 cm are associated with the slump features.

Interpretations:

The cross-laminated sandstones are interpreted to be the result of migrating small-scale current and combined flow ripples. An abundance of asymmetrical form-sets suggests the domination of low velocity unidirectional currents. The minimum and maximum current velocities needed to generate small ripples is dependent on mean sediment size. For very fine- to fine-grained sediment small ripples are generated at current velocities of 15 to 60 cm/s (Harms *et al.*, 1982). Climbing-ripple (ripple drift) cross-lamination suggests rapid deposition in sediment laden waters (Moslow and Tillman, 1986). Combined flow ripples are an intermediate form of ripple influenced by both currents and waves. Allen (1984), suggested that combined flow ripples are generated in shallower waters than wave ripples. The lack of well developed wave ripples suggests that this facies was probably generated in a current dominated setting.

3.2.4 Facies 4 - Cross-Stratified Sandstone

Description:

Representatives of facies 4 are widespread, numerous, and characterized by trough and planar cross-stratified sandstone (Fig. 3.4 (A-H)). The cross-bedded sandstones occur in solitary or grouped sets making up sedimentary units from 0.15 to 2.5 m thick, and average approximately 1.2 m. Lower bed contacts are either sharp or scoured, and upper bed contacts either sharp or gradational. The planar-tabular sets have both unidirectional and bi-directional dip directions.

The sandstones are subrounded to angular and range from fine- to very coarse-grained. They commonly contain scattered coarse to pebbly sized grains and exhibit rapid and extreme vertical changes in grain-sizes. Sorting is typically poor to very poor in the coarse grained sands, and moderate to poor in the medium-grained sand. Well-sorted sandstones are rare and tend to occur in medium-grained sand. The primary type of cross-bedding is planar-tabular. These cross-beds have apparent foreset dips of 10^{o} - 30^{o} that are either tangential or non-tangential with the lower bounding surface. Trough cross-beds display concave-up foresets that are tangential to the underlying surface and increased in inclination upward to maximum apparent dips of 35^{o}. In both types of cross-bedding individual foresets commonly exhibit normal grading, distinguished by differences in colour, grain size, and degree of cementation.

Mud clasts are commonly found in the sandstones of facies 4. They are either subrounded, angular, or lenticular in shape, and have maximum diameters or lengths that

Figure 3.4 Facies 4 (Large-Scale Cross-Stratified Sandstone)

A) Medium-grained, large-scale planar cross-stratified sandstone. Note the grayish green mud clasts and mud clast molds aligned along bedding plane. Also note the cementing of the coarser grained foresets. The photograph is from Gilwood zone 1 in 10-32-80-8W5, 1709.2 m. Scale bar is 2 cm.

B) Medium-grained, large-scale cross-stratified sandstone. Note the fish bones. The photograph is from Gilwood zone 2 in 1-32-78-8W5, 1730.9 m. Scale bar is 2 cm.

C) Medium-grained, large-scale cross-stratified sandstone. The photograph is from 2-3-78-8W5, 1782.4 m. This location is 3 miles south of the study area. Scale bar is 2 cm.

D) Fine- medium-grained, large-scale cross-stratified sandstone. Note the high angle of the cross-beds and the coarser grained cemented lag. The photograph is from Gilwood zone 4 in 4-10-81-8W5, 1671.2 m. Scale bar is 2 cm.

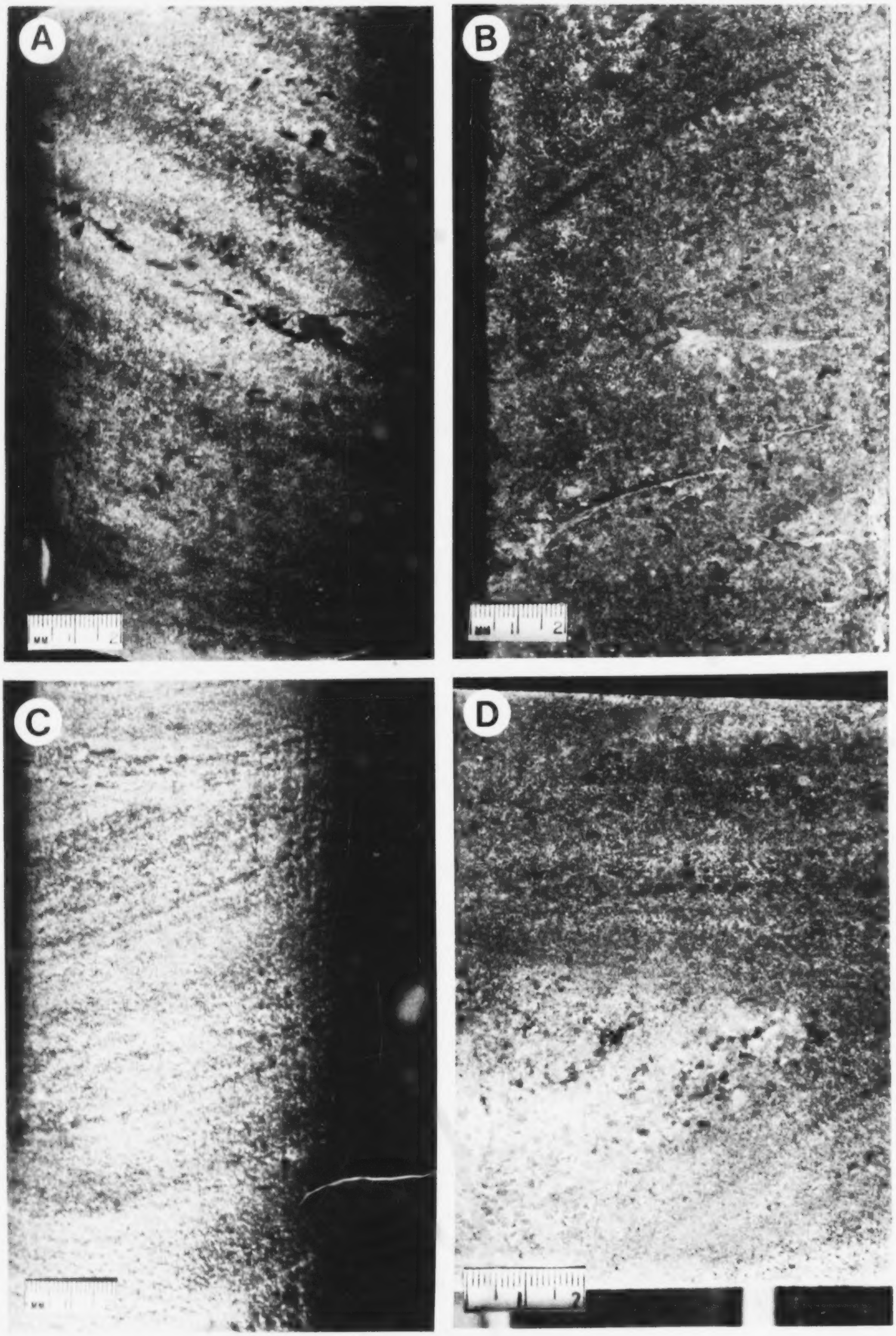
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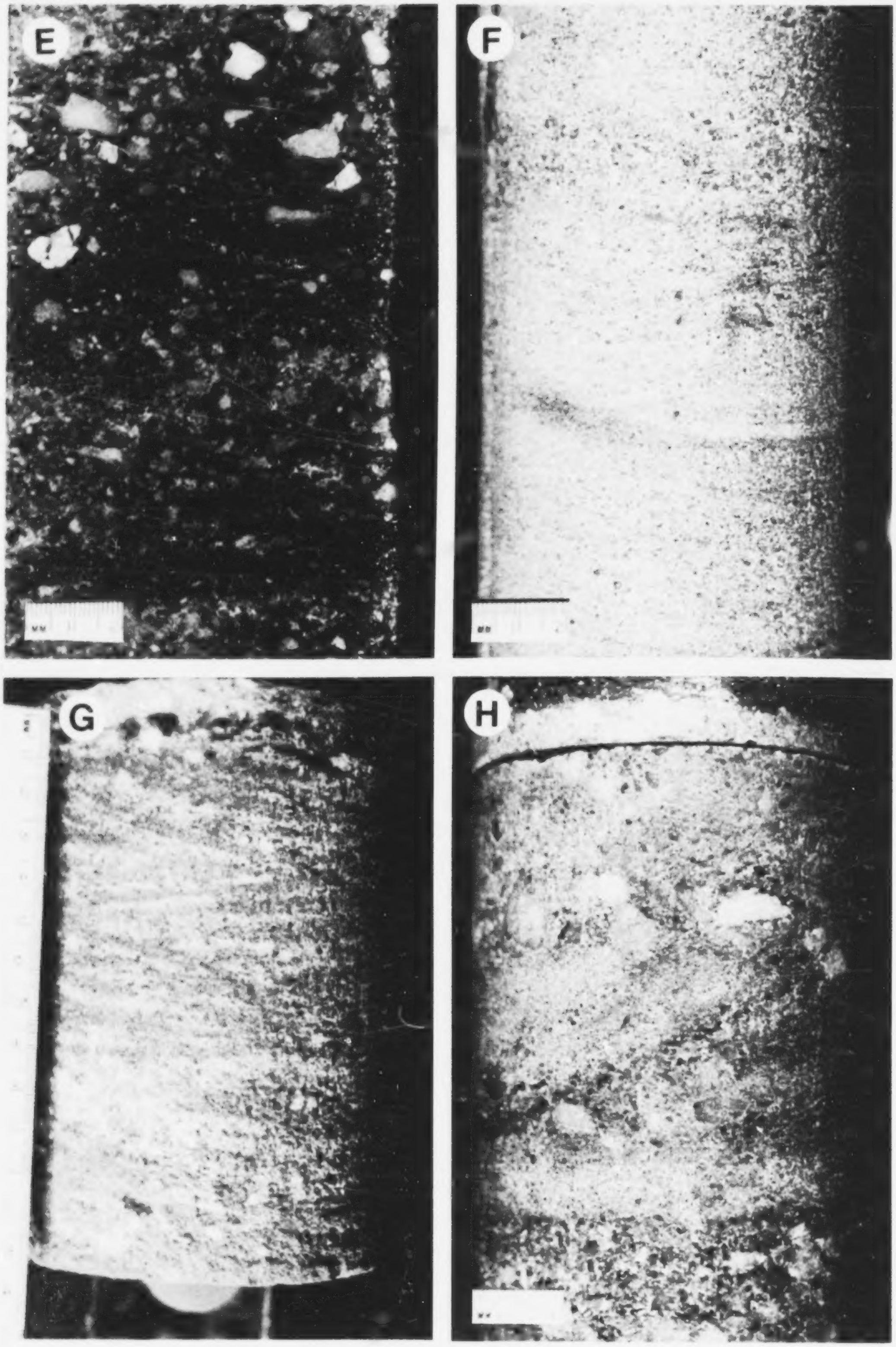
Figure 3.4 Facies 4 (Large-Scale Cross-Stratified Sandstone)

E) Coarse-grained to pebbly cross-stratified sandstone. The photograph is from the base of Gilwood zone 5 in 10-22-78-8W5, 1738.5 m. Scale bar is 2 cm.

F) Medium-grained, large-scale trough cross-stratified sandstone. The photograph is from the base of Gilwood zone 2 in 4-25-80-9W5, 1724.0 m. Scale bar is 2 cm.

G) Coarse-grained, large-scale trough cross-stratified sandstone. Note the cementing of the coarser grained zones. The photograph is from 12-1-80-8W5, 1706.8 m. Scale bar is 2 cm.

H) Medium- coarse-grained, large-scale cross-stratified sandstone. Note the scattered pebbles and the sharp planar upper contact. The photograph is from the upper part of Gilwood zone 5 in 4-10-81-8W5, 1671.2 m. Scale bar is 2 cm.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range from 0.2 to 5.0 cm. They typically exist randomly oriented near the base of cross-bedded units. However, smaller clasts that had a tendency to align with foreset laminae can be located anywhere in the cross-stratified sandstones. Mud clasts are generally preserved, but occasionally the mud was removed leaving only the partial filling of a mud clast mold. The colour of the smaller clasts (0.2 to 2 cm) was either black or shades of green similar to those found in the Watt Mountain Formation mudstones, while the larger (2 to 5 cm) clasts were only black.

Interpretations:

This facies contains cross-stratified sandstones interpreted to be the product of migrating bars or dunes generated by unidirectional fluvial currents. Planar-tabular cross-stratified sandstones with parallel dipping foresets result from down current migration of straight crested (2-dimensional) bars or dunes, while trough cross-stratification is generated by down current migration of sinuous crested (3-dimensional) bars or dunes (Harms *et al.*, 1982). In reality, all bed forms have three-dimensional geometry. However, when describing bed forms from a standpoint of fluid flow, those with a length or breadth that is large compared to their height are referred to as two-dimensional (Allen, 1968). Friend (1965) suggested that the origin of groups of sets of cross-strata is the result of the passage of groups of megaripples, each moving as a result of simultaneous deposition of cross-strata downstream and erosion of material upstream.

Dunes may be generated on the bar tops during low water stages (Miall, 1977). They are asymmetrical flow-transverse bedforms very similar to small ripples in geometry and movement, but are an order of magnitude larger (Middleton and Southard, 1984). The relationship between the sediment size and flow velocity determines whether a dune or ripple will be generated. With increasing mean sediment size, dunes are preferred over ripples at lower flow velocities. For the sediment sizes described in this facies, the lowest range of flow velocity needed to generate dune bedforms ranges from approximately 35 to 65 cm/s (Harms *et al.*, 1982). For grain sizes less than medium to coarse, an increase in flow velocity will produce a change in bedforms from current ripples, to dunes, to a plane bed (upper stage). For sands with a mean grain size greater than medium to coarse, ripples can no longer be generated, and with an increase in flow velocity, bedforms will change from plane beds (lower stage), to dunes, to plane beds (upper stage) (Allen, 1984). Migrating, straight-crested (2-dimensional) dunes produce tabular cross-bedding, and with a higher flow velocity, migrating sinuous-crested (3-dimensional) dunes, commonly linguoid in form, will produce trough cross-bedding (Harms *et al.*, 1982).

The rapid manner in which grain sizes and sedimentary structures change in this facies suggests that it was subject to rapid and variable flow conditions. The distribution of grain size and sedimentary structures suggests that both increases and decreases in flow velocities occurred, sometimes changing very rapidly. Fining upward cycles generally record the waning or progressive decrease in flow velocities; coarsening upward stratification is the result of increased flow velocities. The rare occurrence of mudstone partings contained in the cross-bedded sandstones suggests that current velocities were rarely reduced sufficiently enough for deposition of muds from suspension.

Mudstone intraclasts are interpreted to be rip-up clasts locally derived from either reworking desiccated mud crack-generated fragments or by the hydraulic erosion of cohesive mud laminae or beds. The occurrence of angular mud clasts suggests that transportation before deposition was minimal, because mud clasts round rapidly during transport (Smith, 1972).

3.2.5 Facies 5 - Planar-Laminated Sandstone

Description:

Facies 5 is characterized by very fine- to coarse-grained planar to low-angle ($<5^{o}$) laminated sandstone (Fig. 3.5). Laminae defined by slight changes in grain size and mineralogy, range in thickness from 1 to 9 mm. Pale yellowish brown laminations are composed of sand, grayish green laminations are shale, and the black laminations are mica. The sandstones are poorly- to moderately well-sorted, and may contain scattered coarse to very-coarse grains of quartz, feldspar, and angular green shale clasts (<.5 cm in diameter). Bed thicknesses range from 0.5 to 9 cm and have lower truncation surfaces that are planar or scoured. Upper contacts are found to be either planar, scoured, or gradational. Although this facies dominantly occurs as a single isolated bed, it was associated with facies 3 (small-scale cross-stratified sandstone), and also locally interbedded with laminated and thinly bedded green mudstones in the upper portion of this facies.

Accessory features include thin (<.5 cm) horizontal to wavy mud laminations and flasers, scattered coarser grains and pebbles, and convolute bedding. Rare fish plates are also present.

Interpretations:

The planar laminated sandstone facies is interpreted to represent sediment transport under upper flow conditions. Planar laminated beds can be generated over large areas in either tractional forces generated in lower flow (38 to 58 cm/s) and upper flow velocities (60 to 175 cm/s), or through deposition from suspension fall out. A specific origin for the generation of plane laminations can be ambiguous. However, certain criteria can aid in developing correct interpretations.

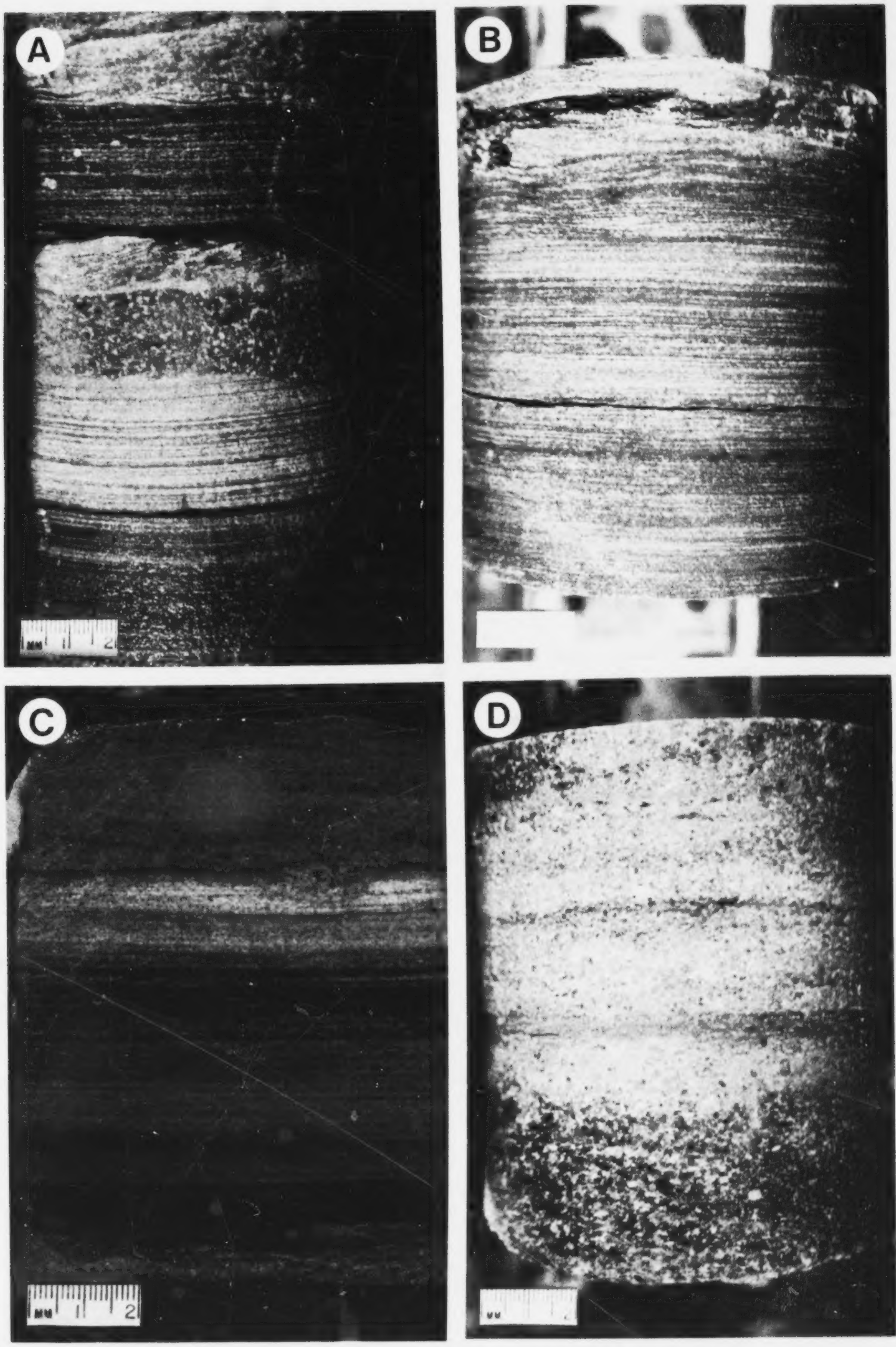
Figure 3.5 Facies 5 (Planar-Laminated Sandstone)

A) Very fine-grained micaceous planar-laminated sandstone. Note the 2 cm massive zone in the center of photograph with scoured base, and the 3 coarse sand grains in the upper planar laminated zone. The photograph is from the top of Gilwood zone 2 in 4-28-79-8W5, 1741.5 m. Scale bar is 2 cm.

B) Very fine-grained micaceous planar-laminated sandstone. The photograph is from Gilwood zone 5 in 4-18-79-7W5, 1704.7 m. Scale bar is 2 cm.

C) Very fine-grained planar-laminated sandstone. The photograph is from the top Gilwood zone 2 in 10-36-78-8W5, 1709.1 m. Scale bar is 2 cm.

D) Medium-grained planar-laminated to thinly bedded sandstone. Note the cyclic finning upward cycles. The photograph is from the top of Gilwood zone 1 in 10-32-80-8W5, 1708.0 m. Scale bar is 2 cm.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Deposition of planar laminated beds by tractional forces rather than suspension fall out can be deduced by the existence of sharp erosional lower bounding surfaces. If the plane laminated beds were generated by suspension fall out, a draping effect over the nonplanar substrate would be produced (Harms *et al.*, 1982). In addition, material coarser than fine sand size cannot be generated through suspension fall out since the current velocities needed to spread out the sediment for substantial distances would create tractional forces. Fine sand sized material can only generate plane laminated beds in upper flow regime conditions. However, if it has been decided that tractional forces were involved in generating the plane laminated beds in sediment sizes >0.7 to 2 mm, additional criteria are needed to distinguish between upper and lower flow origins. If the planar bed is substantially thick it is unlikely that lower-stage transport rates were involved, and when planar laminated beds are interbedded with trough cross-stratified sands an upper-stage condition is suggested (Harms *et al.*, 1982)

The thin mud laminations suggest that the hydrodynamic conditions experienced brief decreases in flow velocity allowing the deposition of the finer muds. The occasional scattered coarse grains in the fine-grained planar laminated sandstones is a reflection of brief increases in flow velocity capable of transporting coarser-grained sediment.

Convolute bedding is the result of the expelling of pore fluid during the earliest stages of sediment consolidation. These type of structures are most commonly associated with water-laid sediments in a setting prone to high rates of sedimentation which prevents excessive packing of the sands (Allen, 1984).

3.2.6 Facies 6 - Massive Sandstone

Description:

The massive sandstone facies is a minor one characterized by a structureless sandstone that is very fine- to coarse-grained, and poorly- to well-sorted (Fig. 3.6). Bed thicknesses range from a few cm to 0.9 m. Lower bed contacts are scoured or gradational, and upper bed contacts are sharp or gradational. The massive sandstones can exist as solitary isolated beds, but they were mostly associated with other facies. The well-sorted massive sandstones are interbedded with facies 5 (planar-laminated sandstone), and the poorly-sorted sandstones, that could also include scattered mud and limestone clasts, are often associated with facies 4 (cross-stratified sandstones).

Interpretations:

Rapid deposition without subsequent tractional transport is the mechanism that likely generated the massive fabric of this facies. Rapid deposition resulted in the development of the poorly-sorted massive sandstones, located at the bases of fining upward cycles. This rapid deposition is supported by the presence of scattered mudstone and calcareous intraclasts. The moderately- to well-sorted massive sandstones are interbedded with planar laminated sandstones, suggesting an association with upper flow regime conditions. Beynon (1991), suggested that rapid deposition in upper flow conditions can suppress the formation of planar laminated beds and result in the generation of a massive fabric.

The appearance of a massive fabric is not always the result of massive fabric generating processes. A massive appearance may be the result of difficulty in recognizing poorly developed sedimentary structures. Renault and Owen (1991) noted

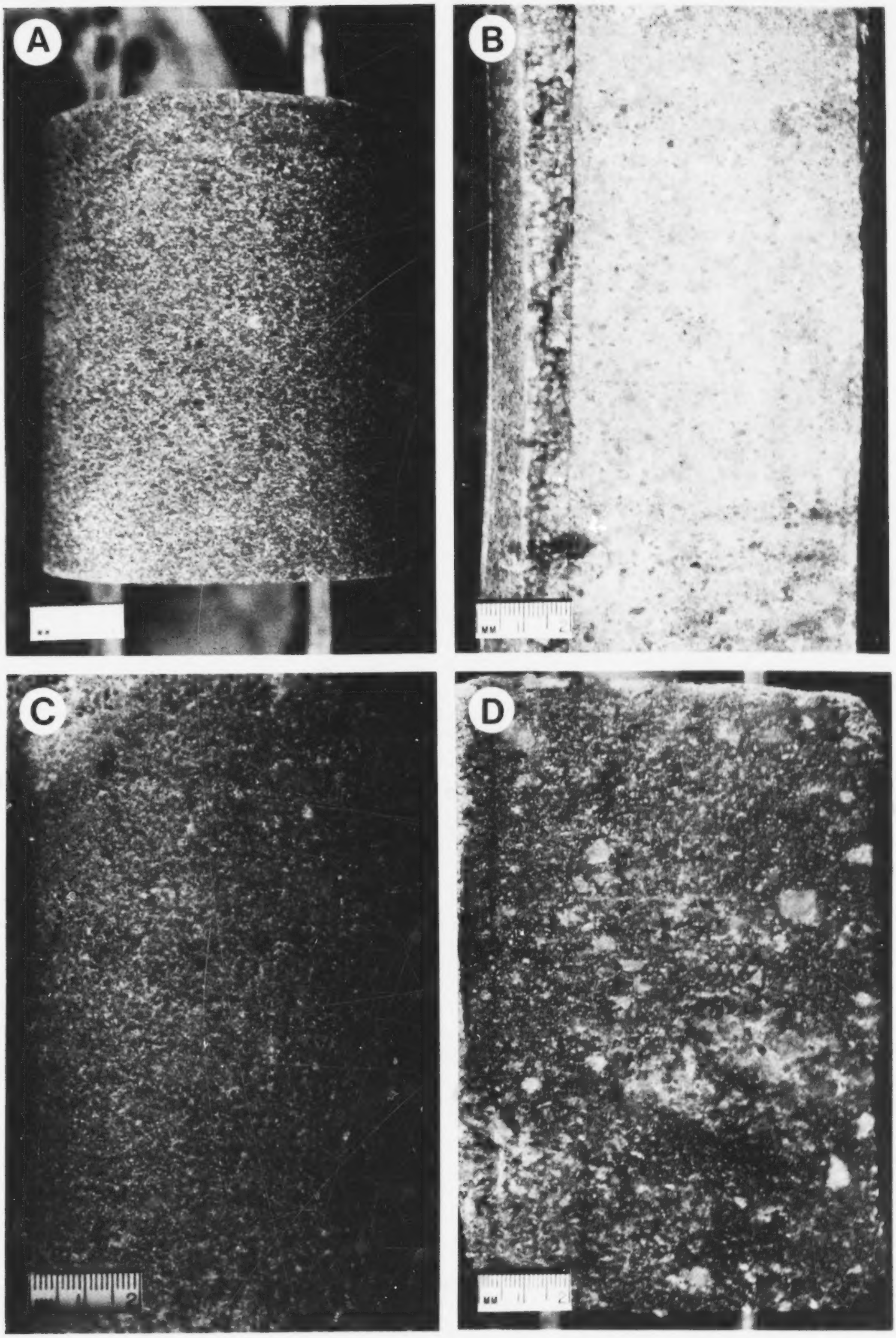
Figure 3.6 Facies 6 (Massive Sandstone)

A) Medium-grained well sorted massive sandstone. The photograph is from Gilwood zone 5 in 12-20-79-8W5, 1691.9 m. Scale bar is 2 cm.

B) Coarse-grained massive sandstone with abundant feldspar. Note that this massive zone is well cemented. The photograph is from Gilwood zone 2 in 4-25-80-9W5, 1721.4 m. Scale bar is 2 cm.

C) Medium-grained well sorted massive sandstone. The photograph is from the base of Gilwood zone 3 in 4-28-79-8W5, 1740.8 m. Scale bar is 2 cm.

D) A coarse-grained massive sandstone overlying a cross-bedded sandstone. Note the pebble size clasts scattered throughout the core and the cemented coarser zones contained in the lower cross-bedded sandstone. The photograph is from Gilwood zone 3 in 2-21-79-8W5, 1745.2 m. Scale bar is 2 cm.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that sedimentary structures in small modern beach bars on Lake Bogoria are poorly developed, and in some cases the sandstones, granules, or pebbles, may appear massive.

3.2.7 Facies 7 - Interbedded Sandstone and Mudstone

Description:

Facies 7 is a minor facies characterized by a platy to thinly interbedded massive to laminated mudstone and very fine- to coarse-grained sandstone (Fig. 3.7). Interbed thicknesses range from 0.6 to 10 cm, and decrease upward in the interbedded unit. Rare scattered coarse grains occur in both the sandstone and mudstone interbeds.

The sandstones range in grain size from very fine-grained sand to pebbles. The sandstones are poorly- to moderately-sorted, and some thicker beds may exhibit normal grading. Internal stratification of the sandstones is demonstrated by a variety of sedimentary structures, but in a particular interbedded unit it usually consists of either planar-horizontal and low-angle cross-stratified sandstones, or structureless sandstones. Rare mudstone intraclasts with textures similar to the underlying mudstones can occur in the sandstones. The basal contacts of the sandstone interbeds are generally sharp and planar, or scoured. Mudstone beds are massive to laminated and are commonly very sandy. In the mudstones are occasional isolated lenticular sand bodies and extremely rare small cracks filled with fine-grained sandstone. A cross-sectional view of these cracks displays an irregular shape with a sub-vertical to vertical orientation, which extended downward approximately 0.5 cm from the base of an overlying sandstone unit. Basal contacts of the mudstone beds are typically sharp and conformable to the underlying sandstone, but gradational forms also exist.

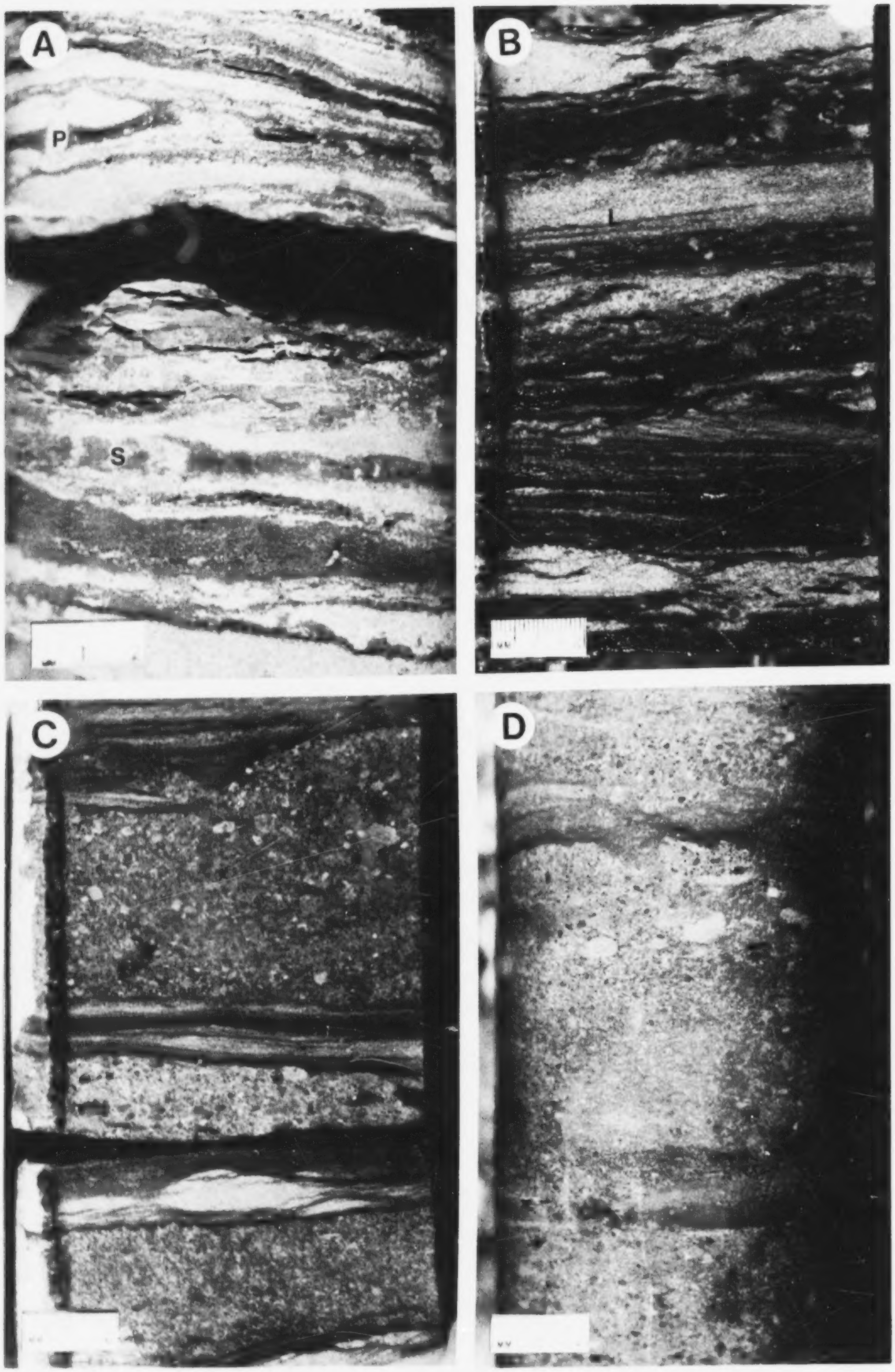
Figure 3.7 Facies 7 (Interbedded Sandstone and Mudstone)

A) Thinly interbedded fine-grained sandstones and grayish green mudstones (Type A). Note the shrinkage cracks (S) and the rare occurrence of *Planolites* (P). The photograph is from the base of Gilwood zone 5 in 4-18-79-7W5, 1708.1 m. Scale bar is 2 cm.

B) Thinly interbedded fine-grained sandstones and grayish green mudstones (Type A). Note the planar laminated sandstone bed (L), syneresis cracks, and the scattered coarse grains. The photograph is from the upper part of Gilwood zone 2 in 10-19-80-8W5, 1716.1 m. Scale bar is 2 cm.

C) Interbedded coarse-grained poorly sorted sandstones and grayish green mudstones (Type B). Note the massive appearance of the sandstone interbeds. The photograph is from Gilwood zone 3 in 10-19-80-8W5, 1745.2 m. Scale bar is 2 cm.

D) Interbedded coarse-grained poorly sorted sandstones and grayish green mudstones (Type B). Note the massive appearance of the sandstone interbeds. The photograph is from a unit below Gilwood zone 2 in 12-18-80-8W5, 1725.3 m. Scale bar is 2 cm.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Fish remains in the form of plates are present. Biogenic structures are extremely rare and are limited to occurrences of *Planolites*.

Interpretations:

The interbedded nature of the sandstones and mudstones is a result of alternating depositional processes. The mudstones are simply a result of suspension fallout during periods of low energy, while the sandstones represent a variety of depositional processes. Planar and low angle cross-stratified sandstones reflect varied flow velocities during deposition involving tractional transport. The planar horizontal beds with sharp lower contacts are generated in upper flow tractional settings similar to facies 5, while the cross-laminated sands represent sediment transport in lower flow tractional settings similar to facies 3. Poorly sorted massive sandstone interbeds consisting of medium- to coarse-grained sandstones reflect rapid deposition through suspension fallout without subsequent tractional transport. The high relief exhibited on the upper sandstone contacts of some massive sandstone interbeds suggests that some of these deposits may have been formed by mass emplacement. Mass emplacement can result when the concentration of settling sediment becomes unstable on an inclined surface (Harms *et al.*, 1982).

The small fine-grained sand-filled cracks are interpreted to be shrinkage cracks whose origin has not been determined. Shrinkage cracks can form at the sediment-air interface by desiccation processes and at the sediment-water interface or substratally by syneresis processes (Plummer and Gostin, 1981).

3.2.8 Facies 8 - Mixed Sand and Mud

Description:

Facies 8 is characterized by a homogenous mixture of sand and mud (Fig. 3.8). The mixture has varying sand to mud ratios that can increase or decrease upward. Muds are typically green, and the sands, which vary from fine to very-coarse, are poorly sorted. The facies can be up to 1.4 m thick and dominantly occurred near sandstone-mudstone contacts. Rarely the mixed sand and mud had a convoluted fabric. Commonly associated with this facies are modest amounts of scattered calcareous clasts ranging in size from 0.2 to 3 cm, and partially cemented calcareous zones up to 20 cm thick. The calcareous clasts were irregular in shape, micritic, and were found to replace and surround clastic grains.

Interpretations:

The mixed sand and mud deposits are interpreted to reflect a rapid decrease in flow velocity, which resulted in decreased flow competence and the immediate deposition of sediment. Rapid decreases in flow velocity can occur when sediment-laden fluvial currents enter relative stationary deposits of water. However, in order for three dimensional mixing and appreciable sediment deposition to occur at the point of interaction, the two mixing waters must be equally dense (Elliott, 1986).

Scattered calcareous intraclasts are interpreted to be rip-up clasts, which were derived from either caliche or fresh water limestone deposits. The calcareous cemented zones have the characteristics of caliche deposits formed above the water table in aridland soils (Retallack, 1990).

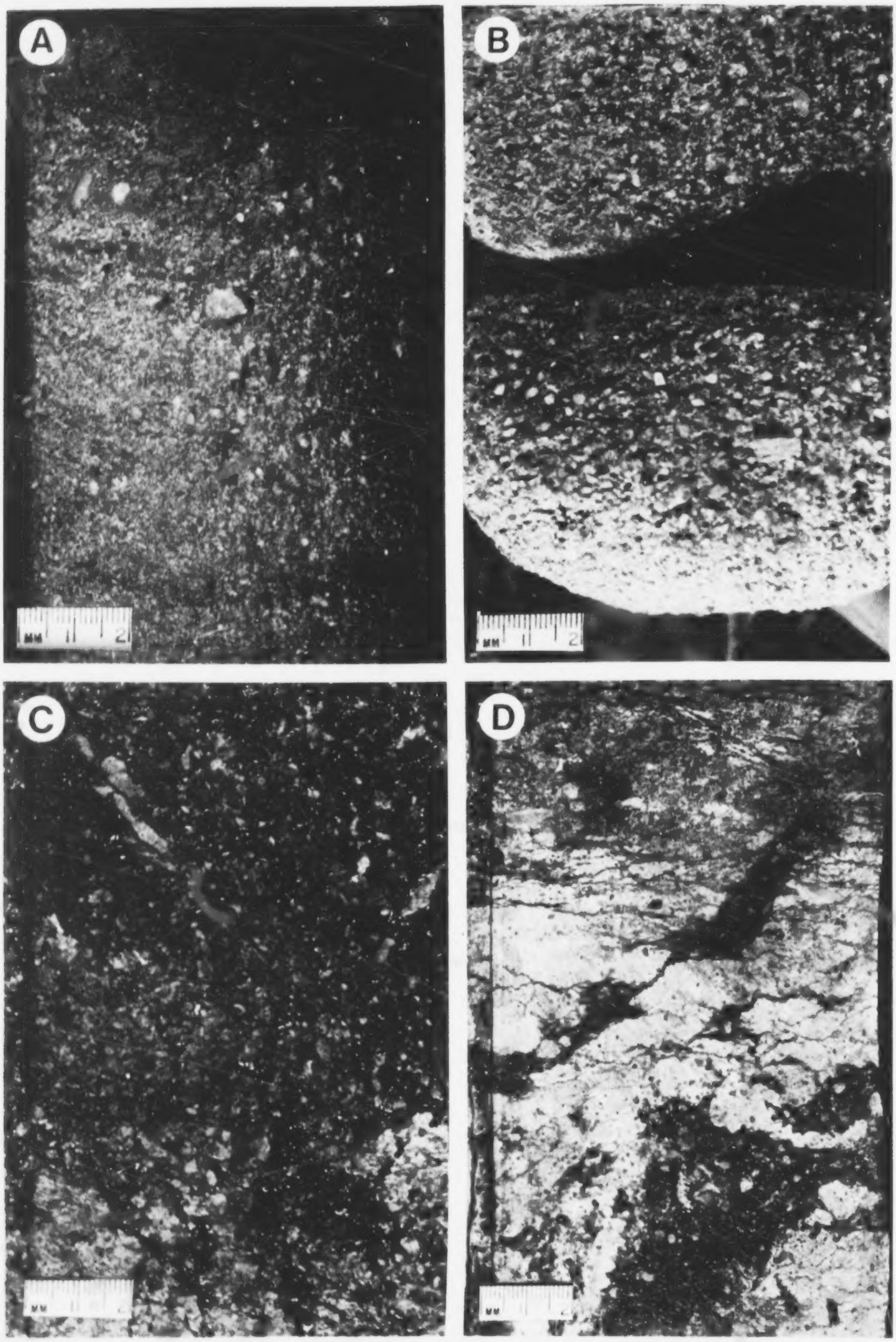
Figure 3.8 Facies 8 (Mixed Sand and Mud)

A) Mixed sand and mud illustrating an upward decrease in sand content. Note the few scattered pebbles. The photograph is from Gilwood zone 4 in 4-28-79-8W5, 1735.6 m. Scale bar is 2 cm.

B) Thoroughly intermixed coarse-grained sand and grayish green mud. The photograph is from Gilwood zone 3 in 10-27-79-8W5, 1724.8 m. Scale bar is 2 cm.

C) Mixed fine- to coarse-grained sand and grayish green mud. Note the moderate amount of calcareous cement. The photograph is from Gilwood zone 3 in 10-27-79-8W5, 1724.3 m. Scale bar is 2 cm.

D) Mixed fine- to coarse-grained sand and grayish green mud. Note the dense concentrations of calcareous cement. The photograph is from a unit below Gilwood zone 5 in 2-21-79-8W5, 1739.0 m. Scale bar is 2 cm.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3.2.9 Limestone

The following limestone description is not a facies in the definable sense, but is a localized unit with a recognizable "state."

Description:

Thick (up to 45 cm) solid calcareous zones containing scattered fine- to coarse-grained sand occur in 12-18-80-8W5 and 10-21-79-8W5 (Fig. 3.9). These limestone deposits have a nodular habit and are light gray to cream in colour. Separating the nodules are continuous and discontinuous mudstone laminations.

Interpretations:

Based on the appearance, thickness, and intimate association with lacustrine deposits, these limestones are interpreted to represent accumulations of freshwater carbonates. In shallow waters (<10m), carbonate production is dominantly biogenic or bioinduced (Platt and Wright, 1991). These carbonates were probably deposited in small localized standing bodies of water where charophyte/algal mounds grew. Rottenfusser (1974) analyzed limestones with a similar appearance in the Watt Mountain Formation north of the Peace River Arch, and through isotopic and petrographic analysis he interpreted them to be freshwater in origin.

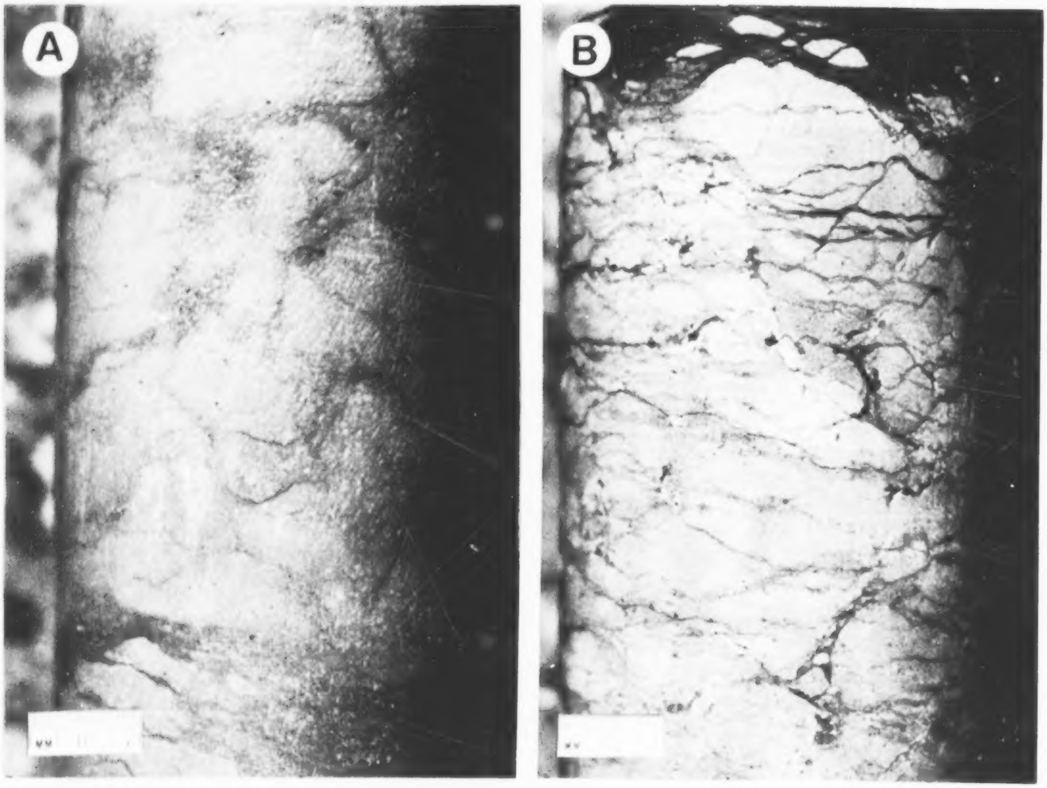


Figure 3.9 Limestones

A) Photograph is part of a 45 cm thick calcareous zone developed below Gilwood zone 2 in 12-18-80-8W5, 1723.6 m. Note the nodular habit and thin discontinuous shale laminations. Scale bar is 2 cm.

B) Dense calcareous zone developed in the upper part of a fine-grained sandstone unit. Note the scattered sand grains, discontinuous mudstone laminations, and the upper contact with a overlying grayish green mudstone. The photograph is from the top of Gilwood zone 3 in 10-21-79-8W5, 1738.5 m. Scale bar is 2 cm.

CHAPTER 4 WATT MOUNTAIN FAUNA AND ICHNOLOGY

4.1 Introduction

Paleontological data from the Nipisi field area has been published by Thachuk (1967), Kramers and Lerbekmo (1967), and Alcock and Benteau (1976). The combination of these studies provided a very comprehensive account of the total fossil content in Watt Mountain Formation. The writer has confirmed the identification of phosphatic brachiopods (*Lingula*), fish remains of the order Antiarchi, and arthropods of the order Conchostraca. The following discussion will examine the environmental significance of all fauna contained in the Watt Mountain Formation of the Nipisi field area, including those identified by the writer, and those referenced in previous studies.

4.2 Watt Mountain Fauna

The phosphatic brachiopods identified as *Lingula* only existed in the basal black shale facies (Facies 1). When *Lingula* and other normally benthic forms are found in black shale environments they are usually interpreted to be epiplanktic (Ettensohn & Barron, 1981). McCollum (1988) however, suggested that a *Lingula* infauna may develop in a shallow epeiric sea with reduced salinity. This interpretation is favored for *Lingula* occurring in the Nipisi field area because similar conditions likely existed during time of deposition. Considering the thin black shale facies is encased between evaporites and lacustrine mudstones, both of which are shallow water deposits, it is unlikely that during the limited time of black shale deposition, a significant deepening event occurred in the area. The reduced salinity conditions required for the existence of *Lingula* in McCollum's (1988) model probably developed in the Nipisi area when periods of elevated fresh water inflow caused the mixing of fresh and marine waters.

Of the fifty-two cores examined, thirty-three contained fish remains in the form of plates, scales, bones, and teeth. Fish remains were mostly present in the lower 0.3 m of mudstone deposits, and only rarely in the sandstones or the middle to upper portions of mudstone deposits. Thachuk (1967) identified these fish remains to be from the order Antiarchi and family Asterolepidae. These were armored fish considered to have been bottom-living forms that inhabited fresh to possibly brackish waters (Thachuk, 1967). Middle to Upper Devonian fish remains from other areas have similarly been interpreted to have fresh to brackish water origins. Devonian "fish beds" from the Old Red Sandstone deposits of Scotland and Ireland were interpreted as freshwater lake deposits (Trewin, 1986). Gordon (1988) however, stated that although most fish from the Middle to Upper Devonian Catskill Magnafacies have been assumed to represent freshwater species, some evidence suggested that the fish may have lived in brackish to even marine conditions.

Combining the observations of Thachuk (1967), and Alcock and Benteau (1976), two types of charophytes, *Eochara wichendeni*, and *Chovanella burgessi*, have been identified in the Watt Mountain Formation mudstones and in some of the upper Gilwood sandstones. Charophytes are calcareous green algae of the genus *Chara* that can be found in both modern and ancient lakes (Dean and Fouch, 1983). They are common on lake margins were they grow on low energy substrates down to 15-20 m depth (Cohen and Thouin, 1987). Because they contain both internal and external $CaCO_3$, charophytes are a major source of biogenic carbonate (Dean and Fouch, 1983).

Alcock and Benteau (1976) classified samples of Conchostracas from Nipisi as *Asmussia membranacea*, and *Ulugkemia sinuata*. Conchostracas are crustaceans that commonly live in ponds or other small temporary bodies of water. A few species however, have also been located in coastal salt flats (Robison and Kaesler, 1987).

4.2 Ichnology

Trace fossils can be found throughout a range of marine and nonmarine environments, and examples of trace fossil assemblages have been documented in rocks of similar and older age than the Watt Mountain Formation (cf. Bradshaw, 1981; Vos, 1981; Pollard *et al.*, 1982; Gordon, 1988). During examination of cores from the Watt Mountain Formation only very rare examples of *Planolites,* a feeding burrow of a infaunal deposit-feeder, were identified (Ekdale *et al.*, 1984). This single ichnogenera is known to occur in both continental and marine environments, and has also been interpreted to be a facies-independent burrow (Grzegorz, 1985). Therefore, limited information can be directly obtained by the existence of *Planolites.*

Trace fossils can survive in a range of conditions varying from marine to nonmarine; therefore, a distinct lack of them in the Nipisi field area can indirectly provide insight into the environmental conditions that existed during sedimentation of the Watt Mountain Formation in this area. The survival and abundance of invertebrate tracemakers is mainly dependent on factors such as temperature, food supply, moisture levels, salinity, substrate characteristics, and intensity of wave or current agitation (Frey and Pemberton, 1987). Therefore, the limited occurrence of tracemakers suggests that not all of the above mentioned factors were continuously favorable for their survival. Considering the facies making up the Watt Mountain Formation deposits, it is unlikely that factors such as moisture levels, substrate characteristics, or intensity of wave and current agitation would be factors that could inhibit trace fossil occurrence throughout deposition of these facies. Therefore, temperature and food supply are the likely candidates, which may suggest that either paleoclimatic conditions were too hot, or there was a lack of food supply during sedimentation of the Watt Mountain Formation.

4.3 Palynology

Extremely rare fragments of primitive plants, *Psilophytes,* were identified in the cores examined in the Nipisi field area. This lack of flora was consistent with the findings of other workers who have studied the Watt Mountain Formation in the vicinity of the Peace River Arch. Paylnologic processing by Alcock and Benteau (1976) on three wells in the Nipisi field area revealed only some wood and cuticle, Rottenfusser (1976) discovered limited flora north of the Peace River Arch, and Kramers and Lerbekmo (1967) discovered limited flora in the Mitsue field area. However, during the Middle Devonian other parts of the world were lush with greenery. This indicates that plant growth was somehow discouraged in the Peace River Arch region, perhaps by very hot and dry conditions that occurred over much of the area during this time (Nelson, 1970). These hot and dry conditions are supported by Witzke and Heckel (1988) who placed most of Middle Devonian Euramerica in an arid evaporitic belt.

CHAPTER 5 VERTICAL FACIES ASSOCIATIONS AND INTERPRETATIONS

5.1 Introduction - Facies Association

The term "facies association" was originally defined by Potter in 1959 as "a collection of commonly associated sedimentary attributes" (Miall, 1984). The purpose of this chapter is to describe and interpret the most common sequential associations of the eight facies presented in Chapter 3. An individual facies may provide some evidence to suggest an environment of deposition, but most facies are not exclusively generated in any one environment (Harms *et al.*, 1982). Therefore, in order to increase the significance of an environmental interpretation, it should be based on a grouping of facies that represent recurring facies associations, or genetically related sequences (Collinson, 1969; Walker, 1992). The eight facies in Chapter 3 that represented recurring structures, textures, and biological attributes, were qualitatively grouped into 4 facies associations. The facies in each association were then collectively interpreted with the intent of determining the major paleoenvironment.

5.1.1 Facies Association 1 (Lacustrine Deposits)

Description:

Facies association 1 is characteristically dominated by red or green coloured mudstones (Facies 2) that contain accessory features such as stress cutans, calcareous nodules, and mud cracks. Silty to sandy zones, and thin (2 to 11 cm) fine-to medium-grained sandstone interbeds are common in the mudstones (Fig. 5.1). Internally, the sandstone interbeds are characterized by either planar-laminated (Facies 3) or small-scale cross-stratified sandstones (Facies 5). This association ranges from a few cm to approximately 5 m in thickness, with the thickest deposits located on the eastern edge of

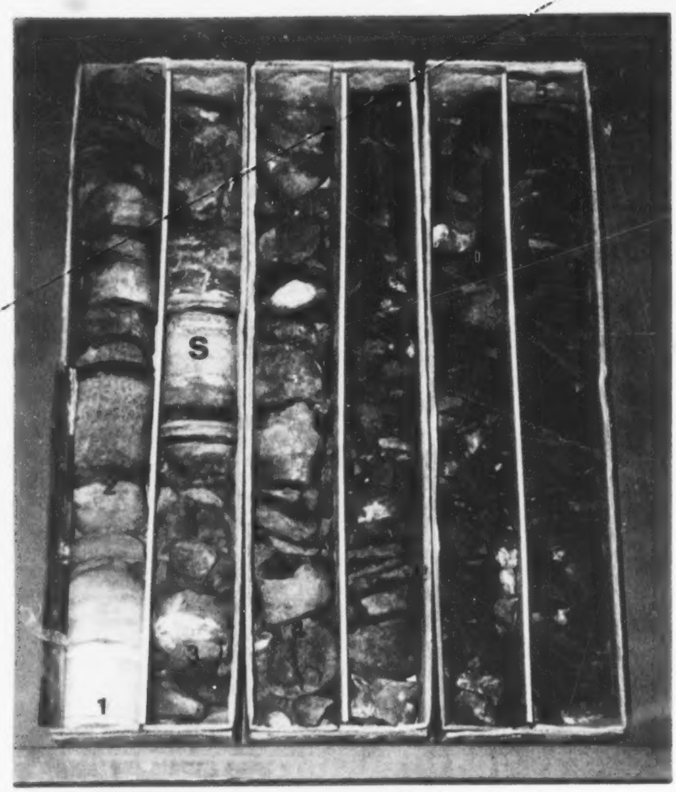


Figure 5.1 Facies Association 1

Cored sequence illustrating the typical siltstones and mudstones of Facies Association 1. This relatively thick sequence with limited sandy zones has developed because of its distal location from the western sourced clastics. The deposits illustrated in the photo include:

1-2 Upper fine-grained sandstone of Gilwood zone 1 gradationally overlain by 10 cm of pale green mudstone. This thin mudstone is a typical illustration of the invariable presence of green coloured mudstones at all mudstone sandstone contacts.
2-3 Dark reddish brown blocky mudstone exhibiting septarian cracking.
3-4 Blocky mudstone dominantly grayish green with scattered dark reddish brown patches. Fish scales and small slickensides were present above the sandy zone (s).
4-5 Dark reddish brown blocky mudstone that is fissile in part.

The photograph is from 10-19-80-7W5, 1691.4-1686.8 m. Scale bar is 40 cm.

the Nipisi field and become progressively thinner toward the west. Fish fragments and *Chara* were the most prevalent fauna.

Interpretations:

Facies association 1 is interpreted to represent an accumulation of deposits in a fresh to brackish water lacustrine environment. This interpretation is based on the lithologic, paleontologic, and sedimentologic characteristics of the facies in this association (Fig. 5.2).

The mudstone deposits that accumulated by suspension fallout in a relatively low energy hydrologic system (Chapter 3) are interpreted to have been deposited in a lacustrine setting. The presence of charophytes and Conchostracas in the mudstones also supports this lacustrine interpretation since they can both be associated with lakes or small temporary bodies of water (Alcock and Benteau, 1976; Dean and Fouch, 1983). The water chemistry of this lake was likely variable, but the presence of fish fragments of the order Antiarchi in the mudstones suggested that fresh to brackish water conditions existed (Thachuk, 1967). Additionally, because the mudstones dominantly lacked lamination and only fish fragments and not intact fish skeletons were found, deposition was likely from a relatively shallow dominantly unstratified lake (Rogers and Astin, 1991).

The presence of sandy mudstone zones, thin sandstone beds, and subaerially exposed areas in the mudstones, suggests rapidly changing hydrodynamic conditions. Although hydrodynamic changes can occur in both lacustrine and marine environments, lacustrine settings are more susceptible to rapid climatically and tectonically controlled fluctuation because they commonly have narrow facies belts (Platt and Wright, 1991). Subaerial exposure is also a very common feature in lacustrine environments resulting

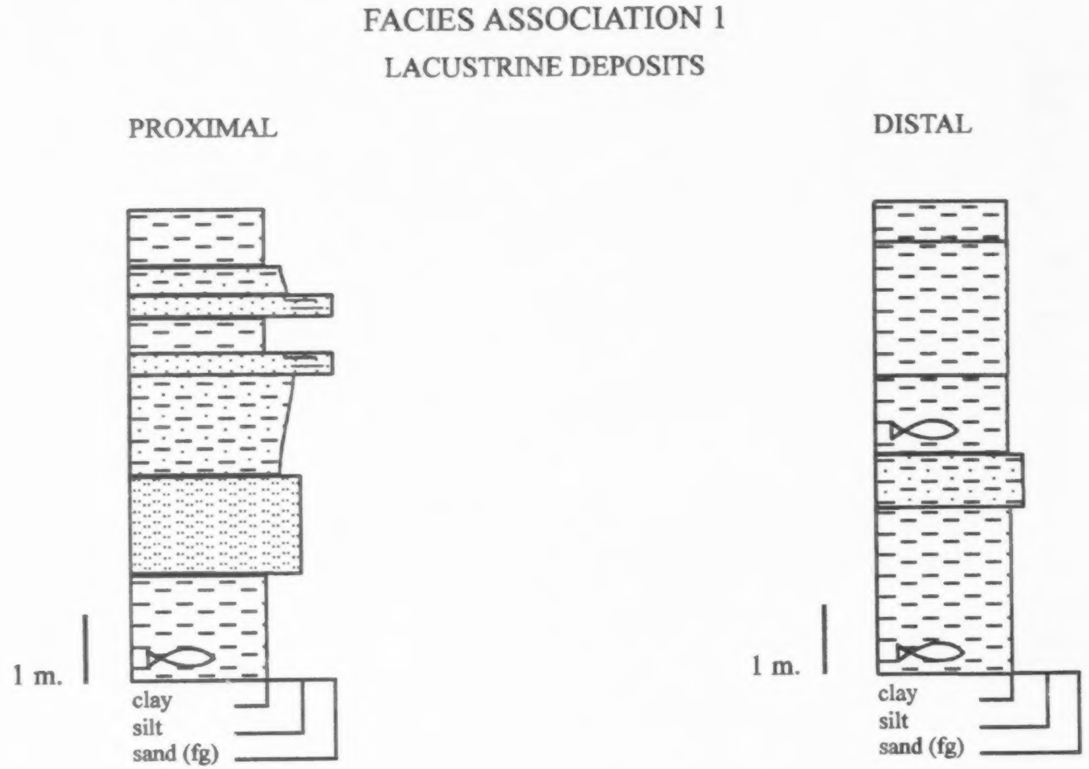


Figure 5.2 Schematic illustration of the typical proximal and distal lacustrine deposits relative to the braid delta plain. Note the decrease in siltstone and sandstone beds in the distal deposits. Description of symbols located in legend of appendix

from oscillations in lake level and shoreline positions (Allen and Collinson, 1986). The lack of evaporites in the Watt Mountain Formation despite frequent subaerial exposure is very significant. It suggests that the lakes were composed of fresh water, which would have inhibited any evaporite formation (Tucker, 1991).

Watt Mountain Formation mudstones and associated sandstone interbeds lack evidence indicating active tidal or strong wave processes. Although large lakes closely resemble shallow seas in processes of deposition and facies patterns, negligible tidal effects and lower wave energies are two differences that can distinguish lacustrine from marine environments (Picard and High, 1972).

5.1.2 Facies Association 2 (Marginal Lacustrine Deposits)

Description:

Facies association 2 is characterized by a coarsening and thickening upward succession of sandstone and mudstone (Fig. 5.3), and is limited in occurrence relative to the fining upward successions in the Watt Mountain Formation. An idealized succession begins with a lower massive mudstone (Facies 2) that grades upward into a mixed silty to sandy mudstone (Facies 8), followed by a unit of interbedded sandstone and mudstone, and an upper unit of thick-bedded coarsening upward sandstone. However, the units of mixed silty to sandy mudstone (Facies 8) and interbedded sandstone and mudstone may be absent. The termination of facies association 2 is indicated when the coarsening upward succession is replaced by either lacustrine deposits or less commonly, scour-based fining upward sandstones.

The upper thick bedded sandstone unit dominates this facies association. It consists of a coarsening upward fairly- to well-sorted sandstone that may be up to 2

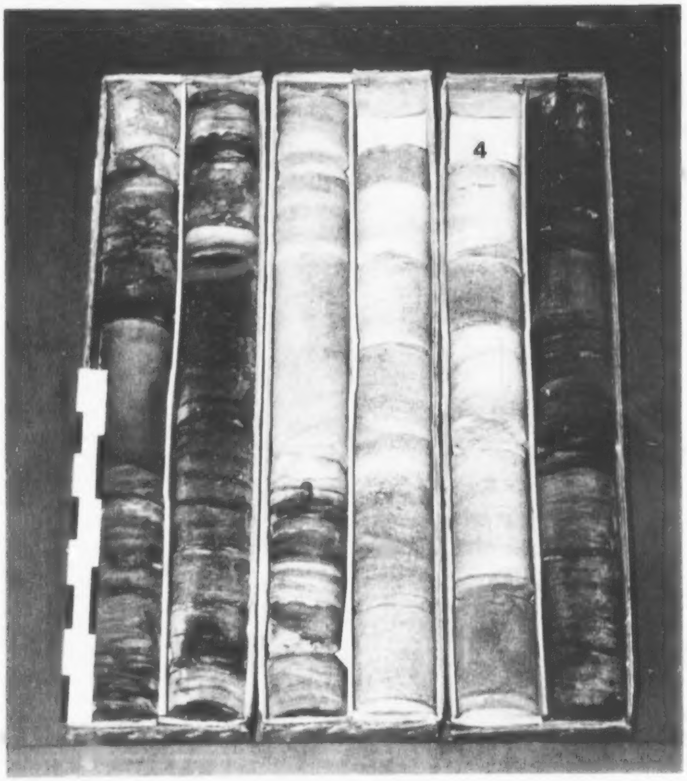


Figure 5.3 Facies Association 2

Cored sequence illustrating a coarsening upward succession of Facies Association 2.

1-2 A lower mudstone.
2-3 A middle interbedded sandstone and mudstone unit. The sandstone interbeds consist of fine-grained planar laminated and small-scale cross-bedded sandstones.
3-4 A upper thick-bedded coarsening upward sandstone dominated by large scale cross-bedding. A fish plate occurs in the upper 0.3 m of this unit.
4-5 An overlying mudstone unit.

The photograph is illustrating Gilwood zone 5 in 12-20-79-7W5, 1690.6-1694.9 m. Scale bar is 40 cm.

meters in thickness. Grain sizes are typically in the medium- to coarse-grain range, but may also be fine-grained or pebbly. Internally the sandstones contain intra-erosive surfaces, and although cross-bedded sandstones (Facies 4) dominate, massive (Facies 6) and planar-laminated (Facies 5) sandstones are present. In the sandstones are mudstone clasts, occasional mudstone laminations, and very rare occurrences of fish remains.

When present, the lower mixed silty to sandy mudstone (Facies 8) and the interbedded sandstone and mudstone portion of facies association 2 are typically 0.3 to 1.0 m in thickness. The interbedded units commonly show upward increases in the relative proportion of sandstone to mudstone. Sandstone interbeds range from very fine- to medium-grained, and internally are typically composed of either massive (Facies 6), parallel laminated (Facies 5), or small scale ripple cross-laminated (Facies 3) sandstones. The mudstone interbeds are mostly green, massive, and contain varying amounts of scattered sand grains and fish remains.

Interpretations:

Facies association 2 (Fig. 5.4) is interpreted to represent deposits generated on lacustrine margins, such as fluvial mouth bars, beaches, spits, and barriers. The fluvial mouth bars formed when fluvial systems entered the lake basin, while the beaches, spits, and barriers, formed by processes commonly associated with low to intermediate wave energy marine environments (Lin Changsong *et al.*, 1991; Allen and Collinson, 1986).

The classic view of deposits generated by prograding mouth bars is often summarized in a single, coarsening-upwards sequence; however, in reality there are bound to be large- and small-scale variations in facies (Elliott, 1986). The upper thick bedded sandstones which represent proximal mouth bar or channel deposits are always preserved in the Nipisi examples. However, rarely present are the distal bar deposits

FACIES ASSOCIATION 2

MARGINAL LACUSTRINE DEPOSITS

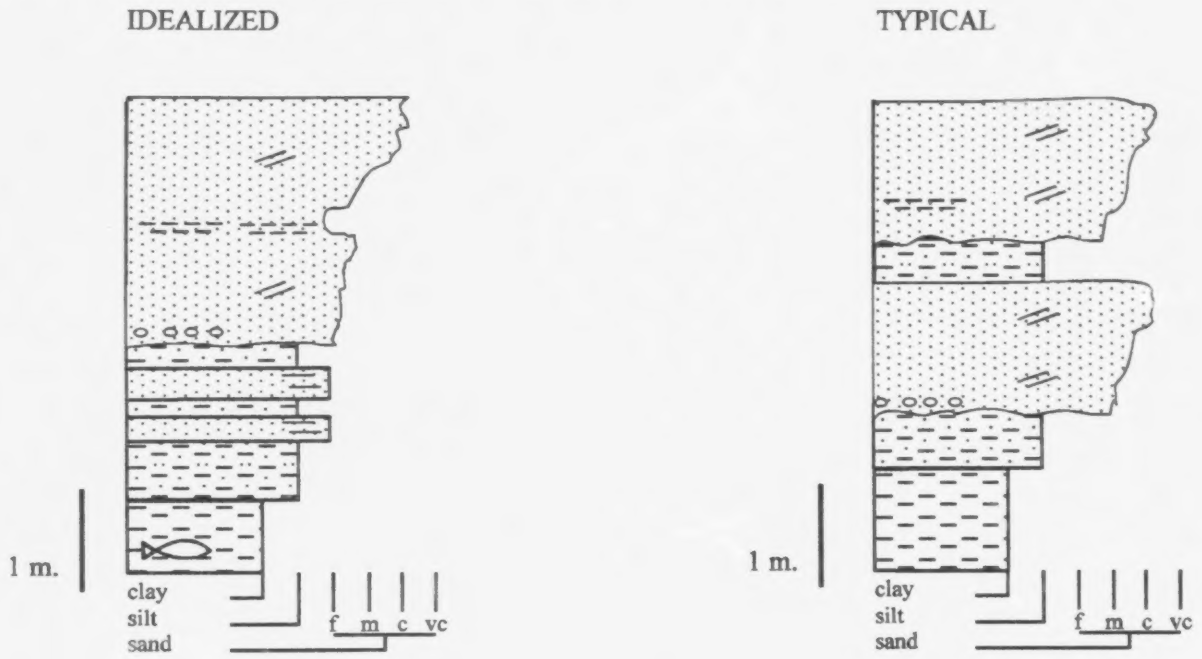


Figure 5.4 Schematic illustration of an idealized and typical marginal lacustrine facies association. Description of symbols located in legend of appendix.

represented by the sandy mudstones and interbedded sandstones and mudstones at the bases of these coarsening-upward successions.

Partial sorting exhibited in some sandstones is a result of minor reworking of sands along the marginal lacustrine areas by waves which dominated the shorelines during the quiescent periods between basin infill stages. These shorelines are interpreted to have occurred in relatively shallow waters, Renaut and Owen (1991) showed that beaches could form in fresh or saline shallow lakes with a mean depth of only 5.5 m.

The limited occurrence of this facies association can be attributed to the lack of tidal and high wave energies, and difficulty in recognition. Marginal lacustrine deposits are difficult to recognize because rapidly fluctuating lake levels may obscure the identification of shoreline processes. Fluctuating levels continually transform shoreline configurations to an extent that effectively inhibits the development of broad progradational shoreline sequences (Picard and High, 1972). In addition, recognition of these littoral deposits also depends greatly on the degree of post-depositional modification (Renaut and Owen, 1991).

5.1.3 Facies Association 3 (Interdistributary Deposits)

Description:

The successions characterizing facies association 3 exhibit considerable variation in facies sequences, consisting of both sandstones and mudstones in a wide range of relative proportions (Fig. 5.5). A general sequence includes a mudstone unit (Facies 2), and variable amounts of fining and coarsening upward sandstone interbeds. The mudstones (Facies 2) commonly contain accessory features such as mud cracks, stress cutans, and calcareous zones and intraclasts, while the sandstone interbeds consist of

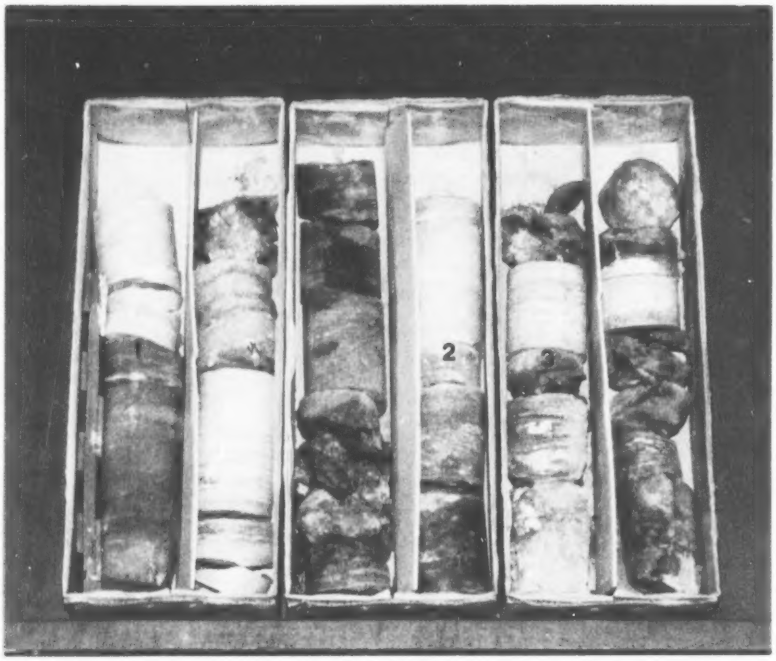


Figure 5.5 Facies Association 3

Cored sequence illustrating the deposits representative of Facies Association 3. The photograph demonstrates the cyclic deposition of silty to sandy mudstone deposits and thin fine- to coarse-grained sandstones. This particular sequence includes 4 fining upward cycles (labeled 1-4). Each cycle contains a lower sharp based sandstone dominated unit overlain by a mixed sandstone and mudstone followed by a sandy mudstone containing scattered calcareous clasts and small slickensides.

The photograph is illustrating Gilwood zone 5 in 10-32-80-8W5, 1697.3-1701.5 m (2.5 m of mudstone is missing at 1700.5 m). Scale bar is 40 cm.

very fine- to coarse-grained cross-laminated (Facies 3) and cross-stratified (Facies 4) sandstones that range up to 0.45 m in thickness.

Interpretations:

Facies association 3 is interpreted to represent an accumulation of deposits generated in the interdistributary areas in the lacustrine braid-delta plain. Interdistributary areas are generally enclosed shallow bodies of water that are quiet or even stagnant, and periodically intruded by deposits normally located in the river channels. The wide range of facies and sequences is a result of the variety of processes, including overbank flooding and crevassing, that can be responsible for the filling of interdistributary areas (Fig. 5.6) (Galloway, 1981; Elliott, 1986).

The mudstone deposits in this association reflect the deposition of fines by suspension fall out during relative quiescent periods in the interdistributary areas, while the sandy bedforms are interpreted to be crevasse events. Crevasse events can generate both coarsening and fining upward sequences that represent progradation and gradual abandonment respectively (Miall, 1985). Deposition in the upper part of interdistributary bay-fill sequences may be indicated by an increased abundance of current generated structures similar to those of facies 3 (cross-laminated sandstone), which is a result of the increasing in energy of the shallower water as the bay fills with sediment (Horn *et al.*, 1978).

5.1.3 Facies Association 4 (Channel Deposits)

Description:

Facies association 4 is characterized by the stacking of fining upward and, less commonly, coarsening upward cycles, which together can generate sandstone-dominated

FACIES ASSOCIATION 3
INTERDISTRIBUTARY DEPOSITS

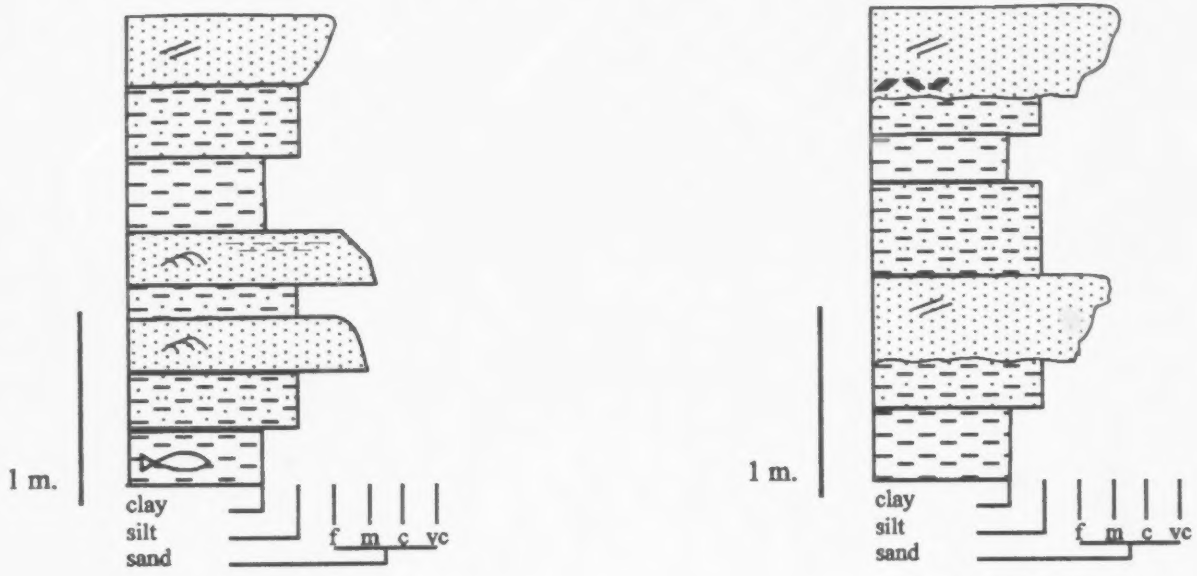


Figure 5.6 Schematic illustrations of interdistributary deposits. Notice the fining and coarsening upward sandstone interbeds. Description of symbols located in legend of appendix.

units up to a few meters thick (Fig. 5.7). Individual cycles are dominated by large-scale cross-stratified sandstones, and are commonly separated by either thin deposits of mudstone (Facies 2) or minor scour surfaces.

A typical fining upward succession begins with a sharp scoured base of low relief (<2 cm) and a coarse grained lag containing randomly oriented mud clasts. Immediately following is a middle unit consisting of large-scale cross-stratified sandstones (Facies 4), and an upper unit made up of cross- and planar-laminated sandstones (Facies 3 and 5 respectively).

Interpretations:

The stacking of fining and coarsening upward sandstone-dominated cycles which characterize this facies association (Fig. 5.8) is a reflection of repetitious channel establishment and abandonment at a given site, and can be attributed to factors intrinsic to the fluvial regime (Allen, 1970). Additional features in these deposits such as the rapid changes in facies showing increases and decreases in flow velocity, and the relatively low abundance of trough cross-stratification relative to planar cross-stratification, are features characteristic of braided channel deposits (Moody-Stuart, 1966; Smith, 1970). Similar associations also interpreted to represent braided channel deposits have been described by Boothroyd and Nummedal (1978), Pollard *et al.* (1982), and Fernandez *et al.* (1988). Braided river systems are characterized by many channels separated by bars or small islands, and when compared with meandering rivers, they have a lower sinuosity, coarser sediment load, and higher width/depth ratio (Miall, 1977).

The development of the braided pattern is a result of complex interactions between sediment supply and water discharge (Collinson, 1986). Braided patterns are preferentially formed under fluvial environments containing excess sediment load and

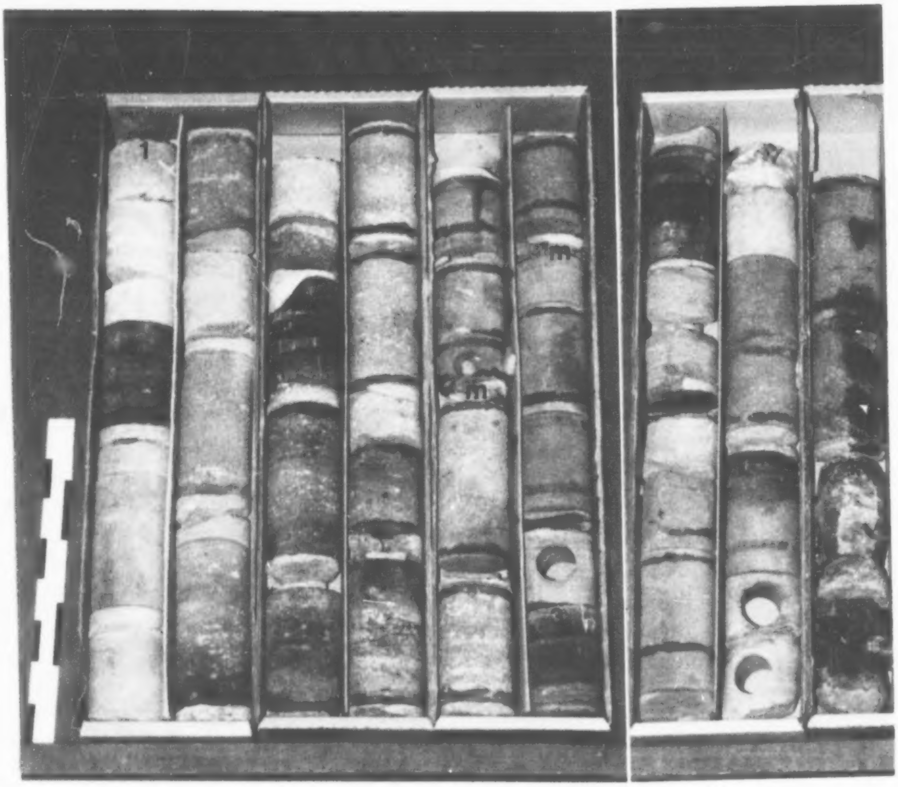


Figure 5.7 Facies Association 4

Cored sequence illustrating stacked fining upward successions representative of Facies Association 4. Within the 3 large-scale fining upward cycles (1-2, 2-3, 3-4) there are numerous fining upward and occasional coarsening upward sub-cycles reflecting rapid fluctuations in flow velocity. The tops of the fining upward sub-cycles occasionally include mudstones (m). This lack of mudstone results in the deposition of a relatively continuous sandstone unit. Fining upward sequences are dominated by large scale cross-bedding in the lower medium- to coarse-grained sandstones, and these grade into an upper finer-grained small-scale cross-stratified or planar-stratified sandstone.

The photograph is from 2-3-79-8W5, 1731.7-1727.1 m (Gilwood zones 3 and 4). Scale bar is 40 cm.

FACIES ASSOCIATION 4

CHANNEL DEPOSITS

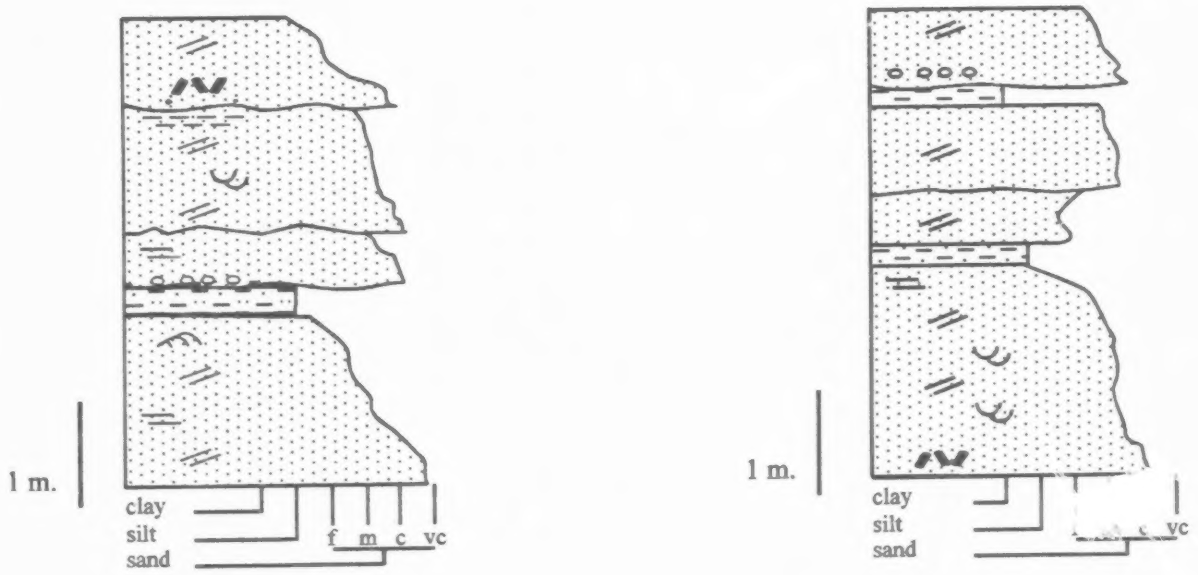


Figure 5.8 Schematic illustration of typical braid-delta distributary channel deposits. Note the stacking of fining upward cycles and rapid changes in sediment type. Description of symbols located in legend of appendix

highly variable discharge rates (Smith, 1970; Boggs, 1987; Miall, 1992). They result from the splitting of flow initiated by the development of mid-channel bars and islands that temporarily store the excess sediment that is available when a river no longer has the capacity or energy to carry its sediment load (Miall, 1992). Given adequate sediment supply, the development of low sinuosity channels is common in arid climates where sporadic discharge rates are common (Elliott, 1986; Miall, 1992).

The lack of flora in sediments of the Watt Mountain formation (Chapter 4) was a significant factor toward the development of braided channels. Braided channel patterns are favored in non-vegetated sediment because of the limited ability to confine channels. Channel banks containing vegetated sediments are more cohesive than non-vegetated banks and result in the development of channels that tend to form meandering rather than braided patterns (Cotter, 1978). Smith (1976) concluded that non-vegetated sediment could be 20,000 times less stable than sediment with 16-18% by volume plant root (Fedo and Cooper, 1989). By decreasing bed load grain size, enhancing fine sediment production, and by increasing bank stability, vegetated sediment has the ability to retard erosion, decrease sediment yield, total runoff, discharge, and flood peaks for a given precipitation period (Schumm, 1968; Cotter 1978).

5.2 Depositional Facies Model For Watt Mountain Sediments

The definition of a facies model was given as "a general summary of a specific sedimentary environment..." by Walker (1984). Based on the four recurring facies associations 1) Lacustrine Deposits, 2) Marginal Lacustrine Deposits, 3) Braid-Delta Plain Interdistributary Deposits, and 4) Braid-Delta Plain Channel Deposits, in the sediments of the Watt Mountain Formation in the Nipisi field area, a lacustrine braid-delta facies model is suggested.

The term braid-delta was defined by McPherson *et al.* (1987) to represent delta formation where braided fluvial systems prograde into standing bodies of water. This type of delta, which has been previously classified as a fan-deltas, has similar shoreline and subaqueous components as a fan-delta, but has been separately classified because of its distinctly different subaerial components. Subaerial components of a fan-delta include an alluvial fan consisting of interbedded sheetflood, debris-flow, and braided-channel deposits, while a braid-delta consist entirely of braided-river or braid-plain deposits (McPherson *et al.*, 1987). Soegaard (1990) suggested that these differences are a direct consequence of the basin margin gradient. Therefore, fan-deltas are more restricted to areas where steep alluvial-fan gradients can be maintained while braid-deltas are not.

A hydrologically balanced system occurs when evaporation and outflow is equal to inflow and precipitation. In the deposits of the Watt Mountain Formation there is evidence suggesting that major periodic changes occurred in the paleoenvironmental conditions. These changes significantly impacted the subcomponents of the lacustrine braid-delta system by changing the hydrologic balance, which is an important control on facies development (Platt and Wright, 1991). The stacking of repetitive facies sequences indicated that the paleoenvironmental conditions were cyclic, with each cycle represented by facies development in either periods when inflow exceeds evaporation or when evaporation exceeds inflow. During these changing conditions it is uncertain whether all facies associations were in existence continuously throughout Watt Mountain deposition. Two end-member paleoenvironmental models (A and B) are suggested for the Nipisi area (Fig 5.9). Model A illustrates the paleoenvironment when inflow exceeded evaporation while in model B evaporation exceeded inflow.

In model A (Fig 5.9), channels in the braid-plain prograded into the lacustrine basin and limited the accumulation of lacustrine deposition to the distal areas. This high

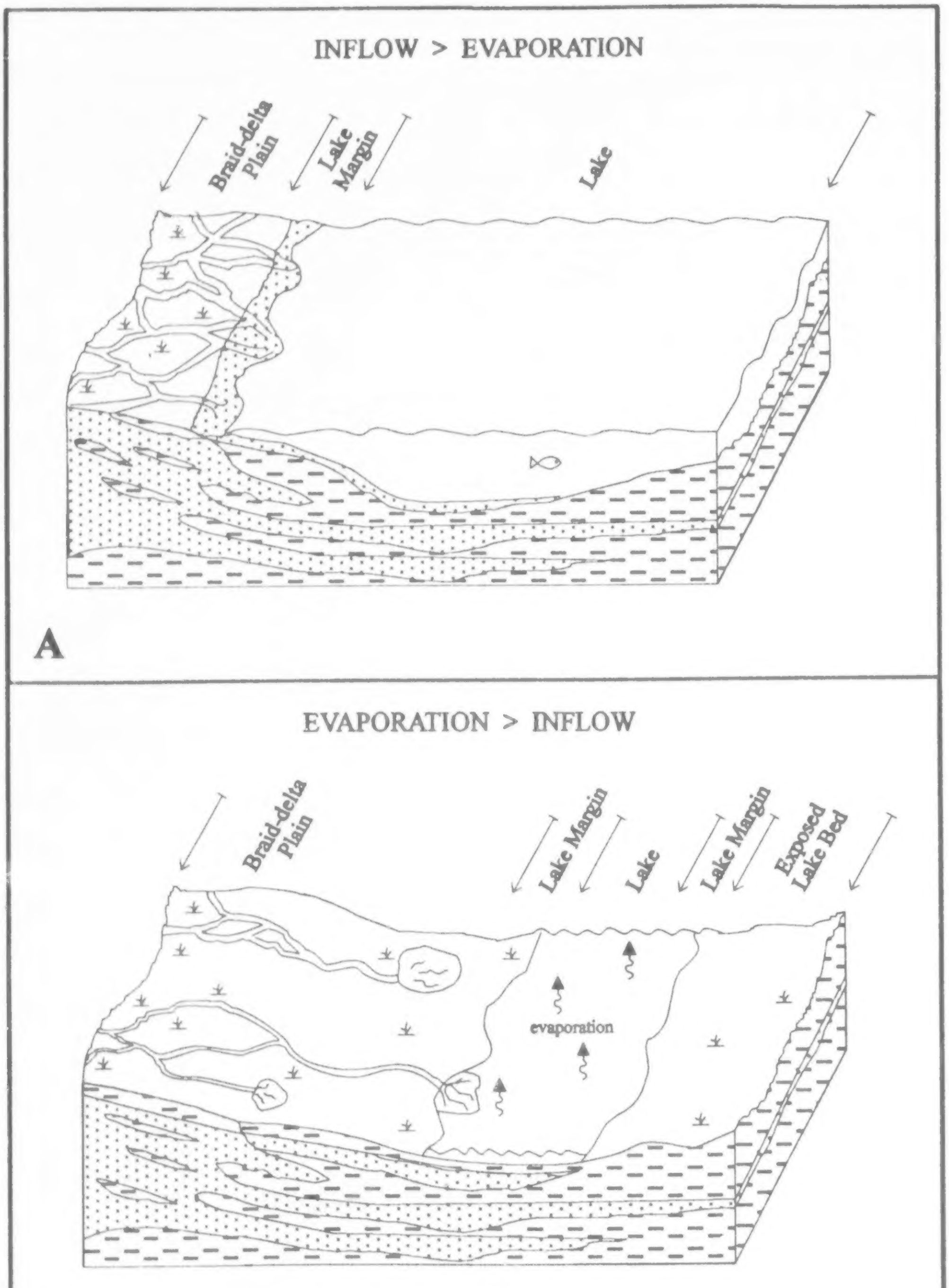


Figure 5.9 Two end-member paleoenvironmental models for the Nipisi field area. (Modified from Rodgers and Astin, 1991)

inflow resulted in elevated lake levels and a landward shifting of the paleoshorlines and their associated facies. At the highest levels the lake may have had outlets; however, the maximum depth of the lake and possible spill level that limited it must remain the subject of speculation. When the braid-plain reached the margins of the lake, individual channels either generated marginal lacustrine deposits or continued subaqueously. Billi *et al.* (1991) explained two processes that allowed the formation of subaqueous channels, both of which may have occurred at Nipisi. The first process initially required braided distributary channels to cut into the lake bottom when it was exposed to subaerial conditions during dry spells. This would make it much easier for channels to continue subaqueously when more humid conditions were re-established, because there would be a pre-established channel path. The alternative hypothesis involved strong hyperpycnal flows that allowed the formation of subaqueous channels since they could easily scour into the lacustrine clays as they entered the lake.

In model B (Fig. 5.9), lowered levels of inflow relative to evaporation resulted in the shifting of paleoshorelines and the exposure of previously submerged areas. During this evaporation phase it was likely that the lake was hydrologically closed, and the lack of prograding channels allowed the deposition of lacustrine deposits throughout the basin, including those areas previously dominated by sandstone deposition. The extreme limit of exposure during the evaporation phase may have been extensive, but the existence of isolated occurrences of fresh water carbonates suggests that small isolated bodies of water remained for some length of time.

CHAPTER 6 STRUCTURE

6.1 Regional and Local Structure

Searching for a geological datum in northern Alberta, Rottenfusser (1974) constructed a structure map on the top of the Slave Point Formation with a 200 feet (61 meter) contour interval. The map covered a 15 square township area and illustrated that the Slave Point top was a nearly planar surface with a dip to the southwest of 4.7 m/km, and was suitable for use as a datum. The regional structure in the Nipisi area (approximately 2.75 square townships) was determined using a 10 m contour interval on this surface (Fig. 6.1), and although there are some distortions to the regularity of the contours, a southwest dip of approximately 5.4 m/km was calculated.

Rottenfusser (1974) expressed concern over using the top of the Watt Mountain Formation as a datum north of the Peace River Arch. His concerns were based on the difficulty in distinguishing between the Watt Mountain and overlying Slave Point Formation, and uncertainties in how flat-lying the top of the Watt Mountain Formation was. Within the Nipisi area, the top of the Watt Mountain Formation can be correlated with confidence, and many workers have used this surface as a datum. The similarity between the Watt Mountain and Slave Point formations structure contour maps, with the exception of some increased nosing of the contours in the northern part of the field, suggests that the top of the Watt Mountain Formation is also a reasonably flat surface (Fig. 6.2). Thachuk (1967) proved that the nosing of contours was a reflection of significant basement topography, which was in excess of 60 meters in the northern Nipisi area.

The contact between the Watt Mountain Formation and the underlying Muskeg Formation is an erosional unconformable surface (Alcock and Benteau, 1976). Although

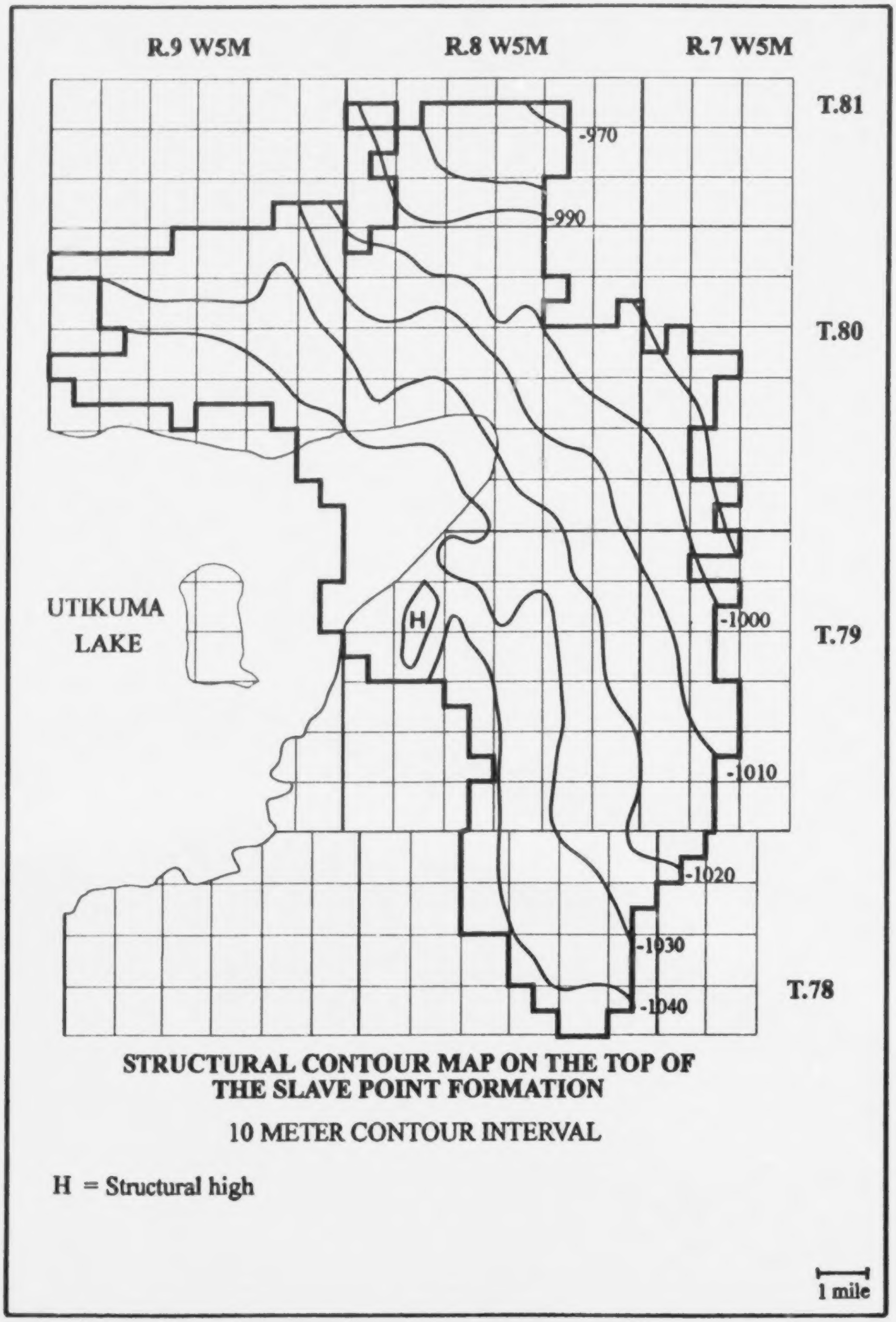


Figure 6.1 Structural contours on the top of the Slave Point Formation.

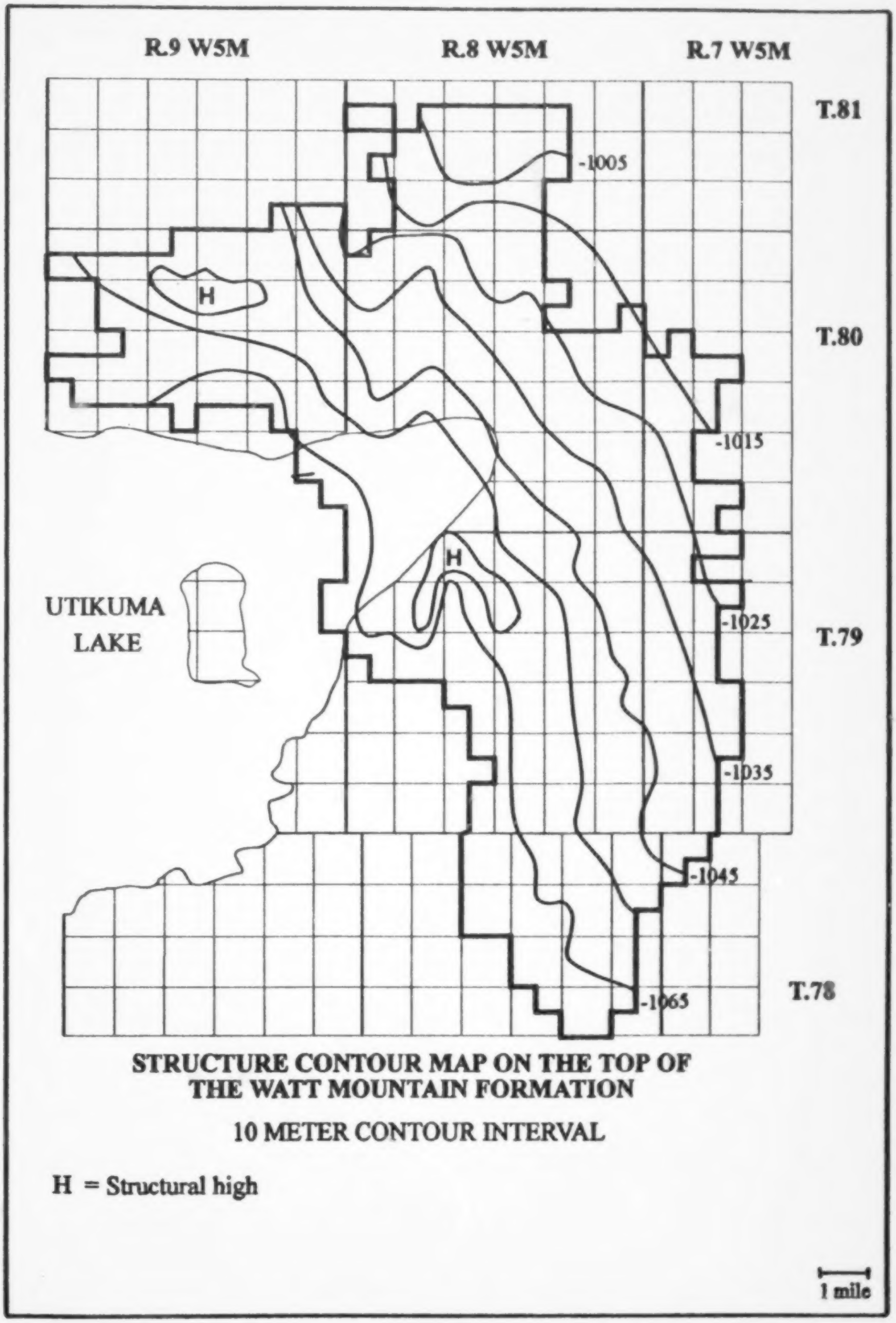


Figure 6.2 Structural contours on the top of the Watt Mountain Formation.

there is a similarity between the structural pattern of the Muskeg Formation top (Fig. 6.3) and the top of the Slave Point and Watt Mountain formations, the top of the Muskeg Formation has a significantly larger averaged southwest structural dip of 7.3 m/km on the eastern part of the field. This difference suggests that the structure of the Muskeg Formation was affected by events additional to those that generated the regional structure in the Nipisi field. A restored structure map of the top of the Muskeg Formation, using the depositionally flat Slave Point Formation as a datum, illustrates a north-south trending trough-like feature within the Nipisi field area (Fig. 6.4). This trough-like feature is clearly visible in a three-dimensional paleostructure diagram of the Muskeg Formation using the Watt Mountain Formation as a datum (Fig. 6.5). The trough resulted in the thick Watt Mountain sediment accumulation in the Nipisi area. A Watt Mountain Formation isopach (Fig. 6.6) illustrates the relationship between thickness of the Watt Mountain Formation and deepness of the trough.

6.2 Origin of Muskeg Trough

Previous studies have suggested that the Muskeg trough was the result of salt solution collapse prior to deposition of the Watt Mountain Formation (Thachuk, 1967 and Alcock and Benteau, 1976). Thachuk (1967) suggested that the salt solution occurred in the thick salt bed located at the base of the Muskeg Formation. Evidence for this was illustrated in an isopach map of this basal salt, which showed the existence of an erosional salt edge located approximately in the center of the Muskeg trough. This basal salt is important because it is the thickest salt bed in the Muskeg Formation. The present study shows, however, that there are many other thinner salt beds that appear to have been removed by salt dissolution, and these also contributed to the thinning of the Muskeg Formation over the Nipisi area.

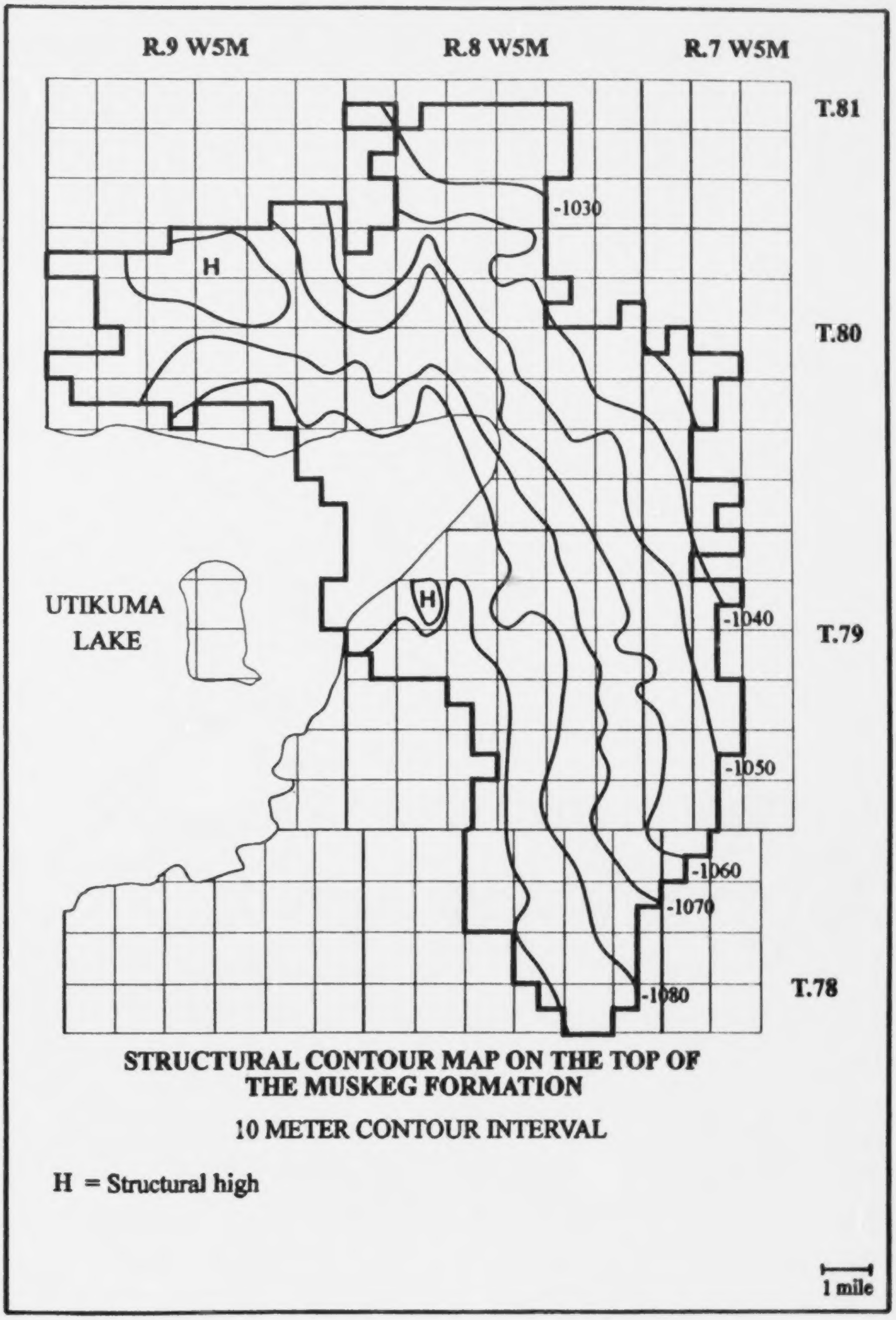


Figure 6.3 Structural contours on the top of the Muskeg Formation.

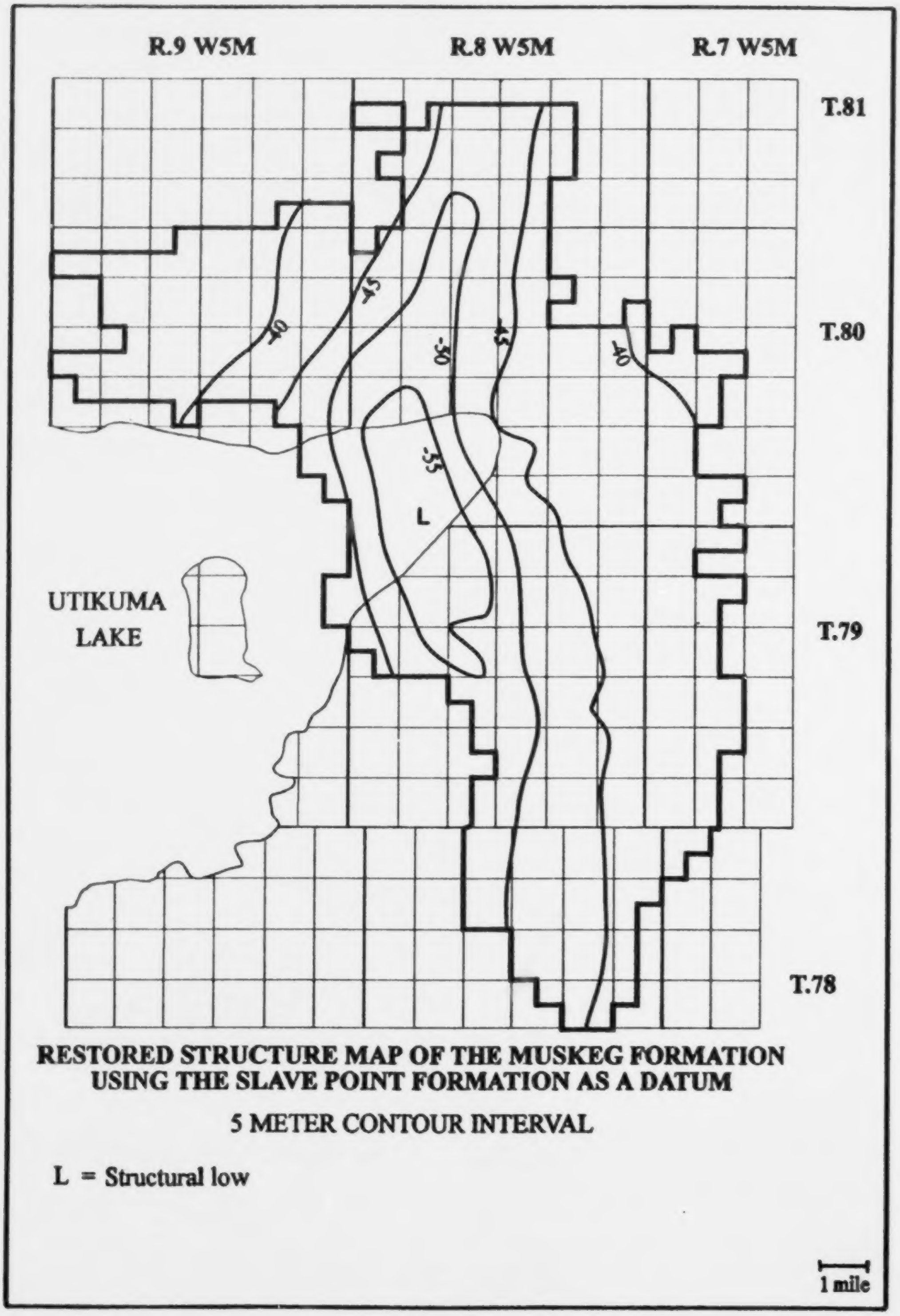
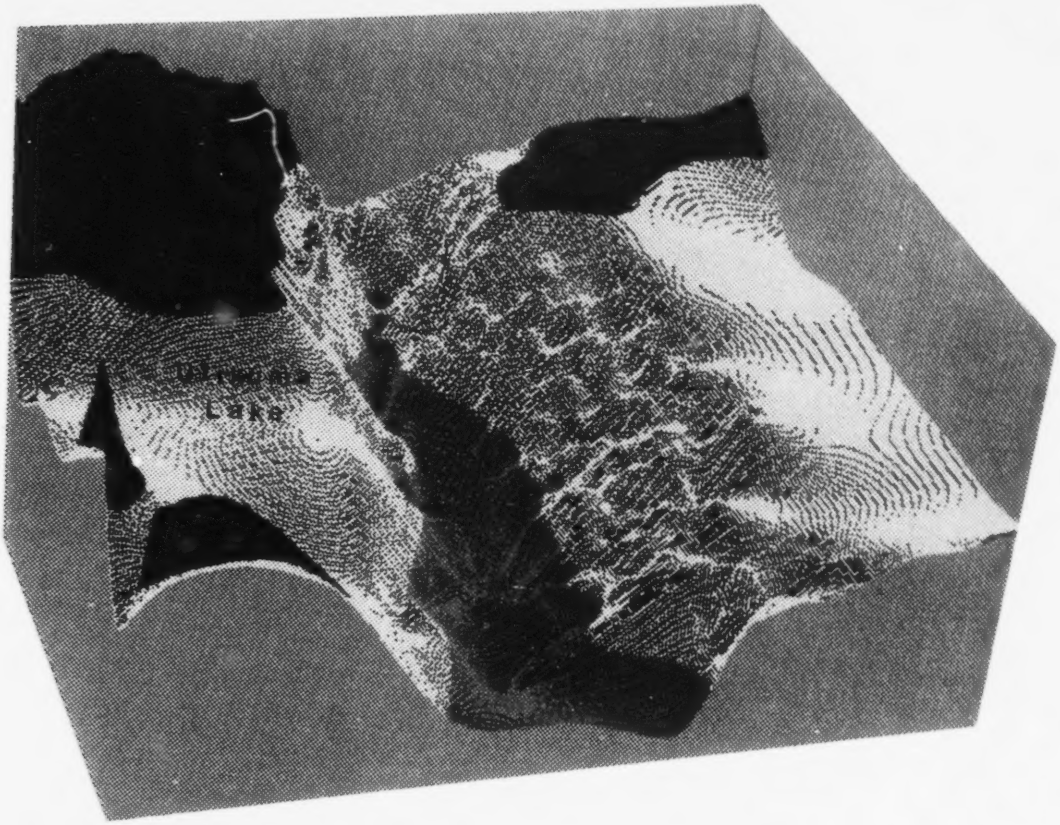


Figure 6.4 Restored Muskeg Fm. structure map using Slave Point Fm. as datum.



▨ Topographical low (Base of Muskeg trough)

■ Topographical high

Figure 6.5 Three dimensional block diagram illustrating the paleostructure of the Muskeg Formation at the end of Watt Mountain time

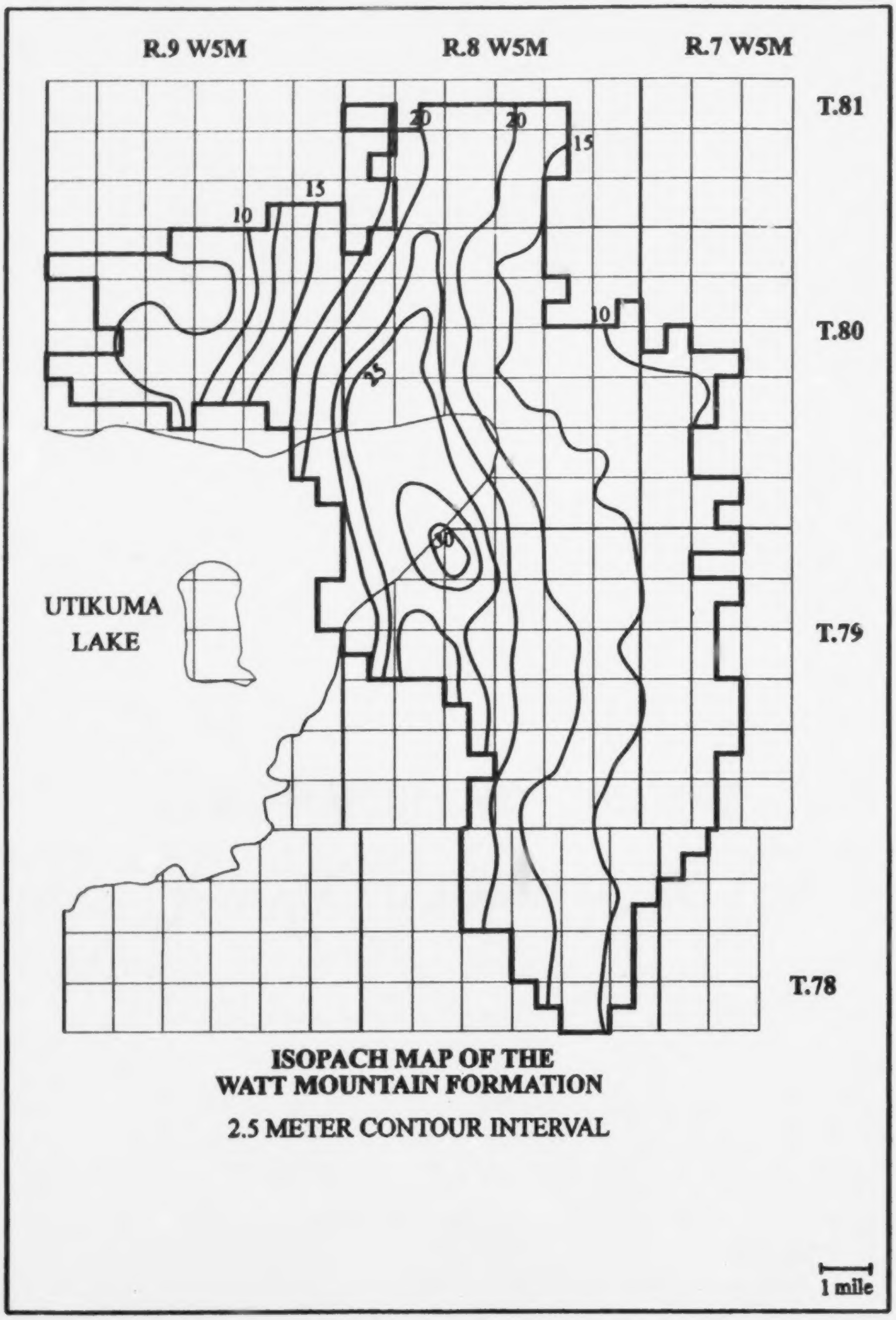


Figure 6.6 Isopach map of the Watt Mountain Formation.

An isopach map of the Muskeg Formation (Fig. 6.7) illustrates that the whole formation gradually thins in a westward direction; therefore, it is not surprising that the total accumulation of salt within the Muskeg Formation would also thin in this direction as demonstrated by Thachuk's isopach map of the lower Muskeg salt (Thachuk, 1967). A problem exists though, as to what causes the increased thickness of the Muskeg Formation to the west of Thachuk's (1976) zero salt edge. To the west of the zero salt edge, there is no lower salt left to explain the increased thickness of the Muskeg Formation. However, the increased thickness of the Muskeg Formation on the western side of the Nipisi area can be explained if all salts in the Muskeg Formation are thought to have contributed to the salt solution collapse. A total salt isopach map was generated by using a 65 μs/ft cutoff on the sonic log (Fig. 6.8). The map illustrates that the thickening of the Muskeg Formation on the western side of the Muskeg trough is associated with a thickening of total salt accumulation.

6.3 Timing of Salt Solution Collapse

The timing of salt solution has been documented by previous workers to have occurred prior to Watt Mountain Formation deposition during a period of Muskeg subaerial exposure (Thachuk, 1967 and Alcock and Benteau, 1976). It is possible that parts of the Nipisi field area experienced limited collapse during this Muskeg exposure period, but detailed mapping of the 6 Gilwood zones suggested that collapsing also occurred during the deposition of the Watt Mountain Formation. In this study, collapse was recorded at the end of Gilwood zone 2, Gilwood zone 4, and at the end of Watt Mountain deposition (Fig 6.9, 6.10, 6.11). A progression of collapse at these time intervals can be demonstrated (Figs. 6.12 to 6.16).

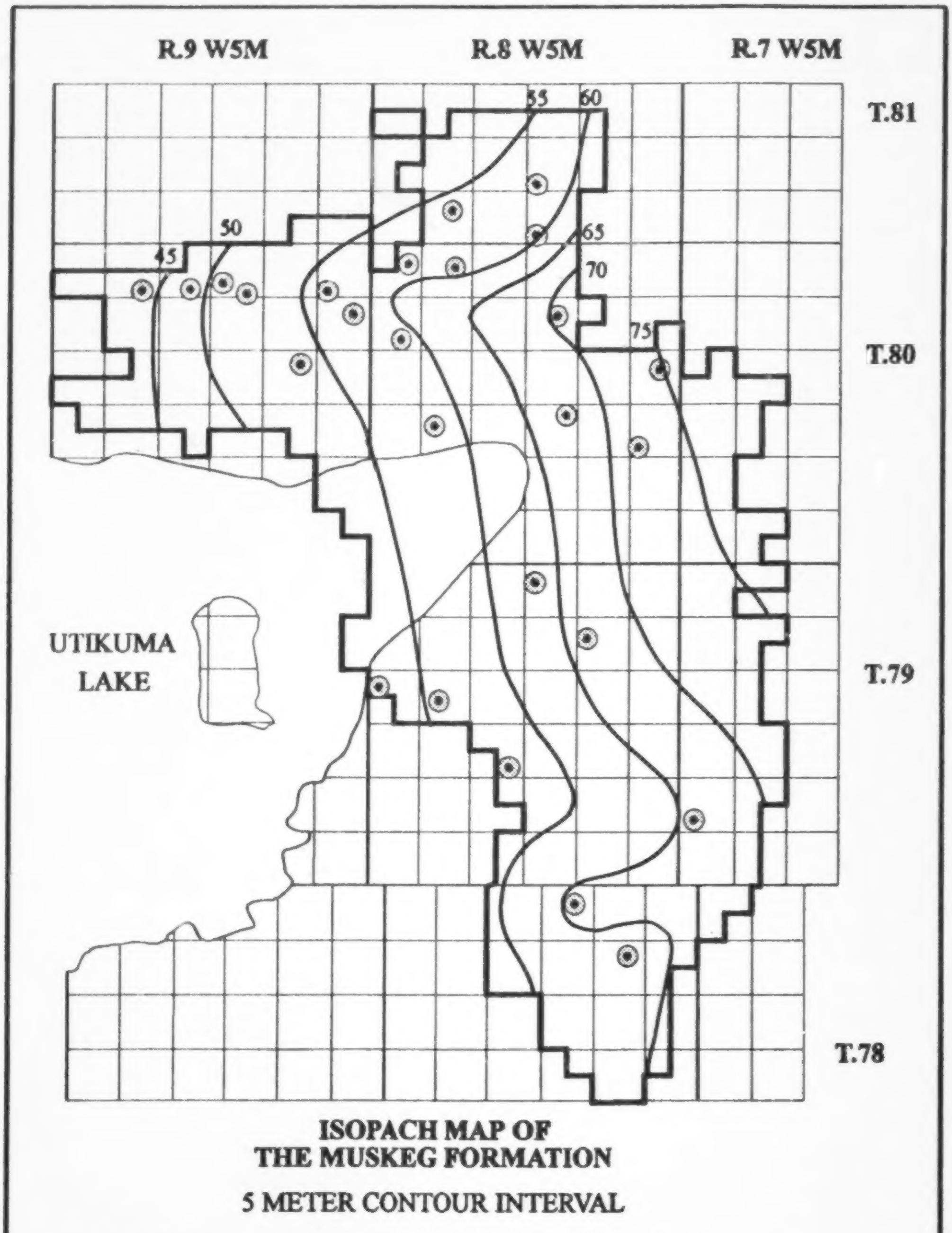


Figure 6.7 Isopach map of the Muskeg Formation

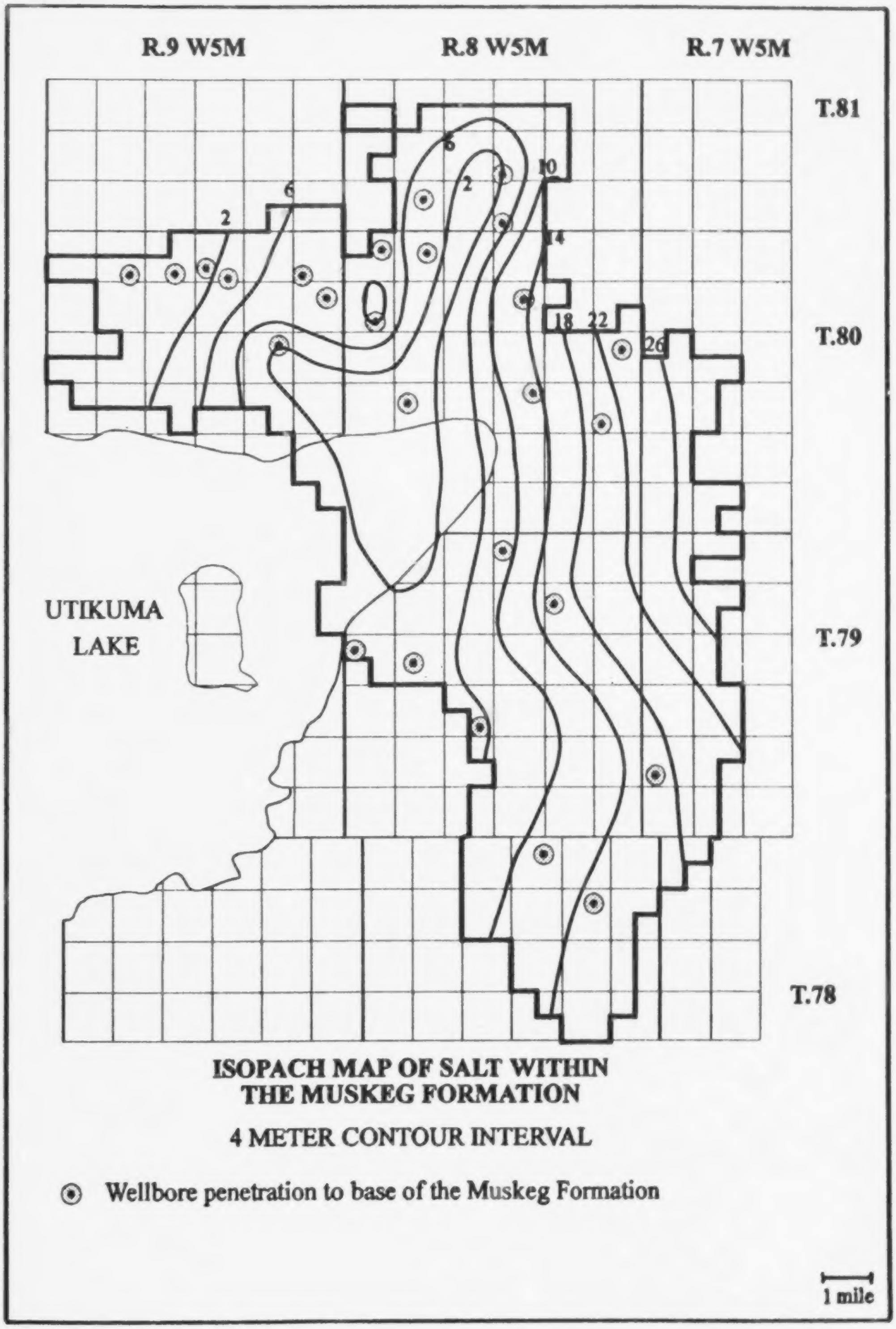


Figure 6.8 Isopach map of salt within the Muskeg Formation.

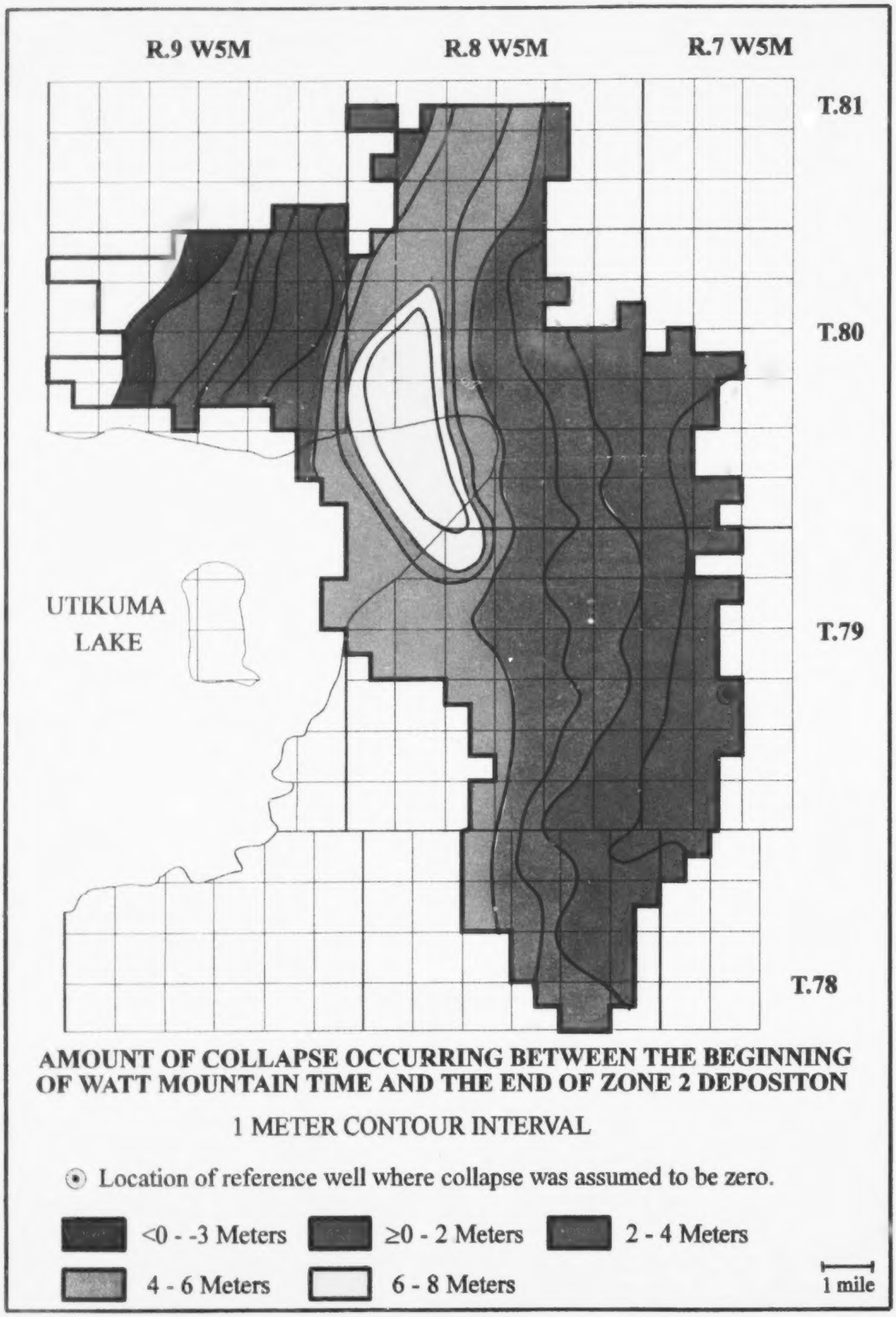

R.9 W5M
R.8 W5M
R.7 W5M
T.81
T.80
T.79
T.78
UTIKUMA LAKE
AMOUNT OF COLLAPSE OCCURRING BETWEEN THE BEGINNING OF WATT MOUNTAIN TIME AND THE END OF ZONE 2 DEPOSITON
1 METER CONTOUR INTERVAL
⊙ Location of reference well where collapse was assumed to be zero.
<0 - -3 Meters
≥0 - 2 Meters
2 - 4 Meters
4 - 6 Meters
6 - 8 Meters
1 mile

Fig. 6.9 Contour map illustrating the amount of collapse occurring between the beginning of Watt Mountain time and the end of Gilwood Zone 2 deposition.

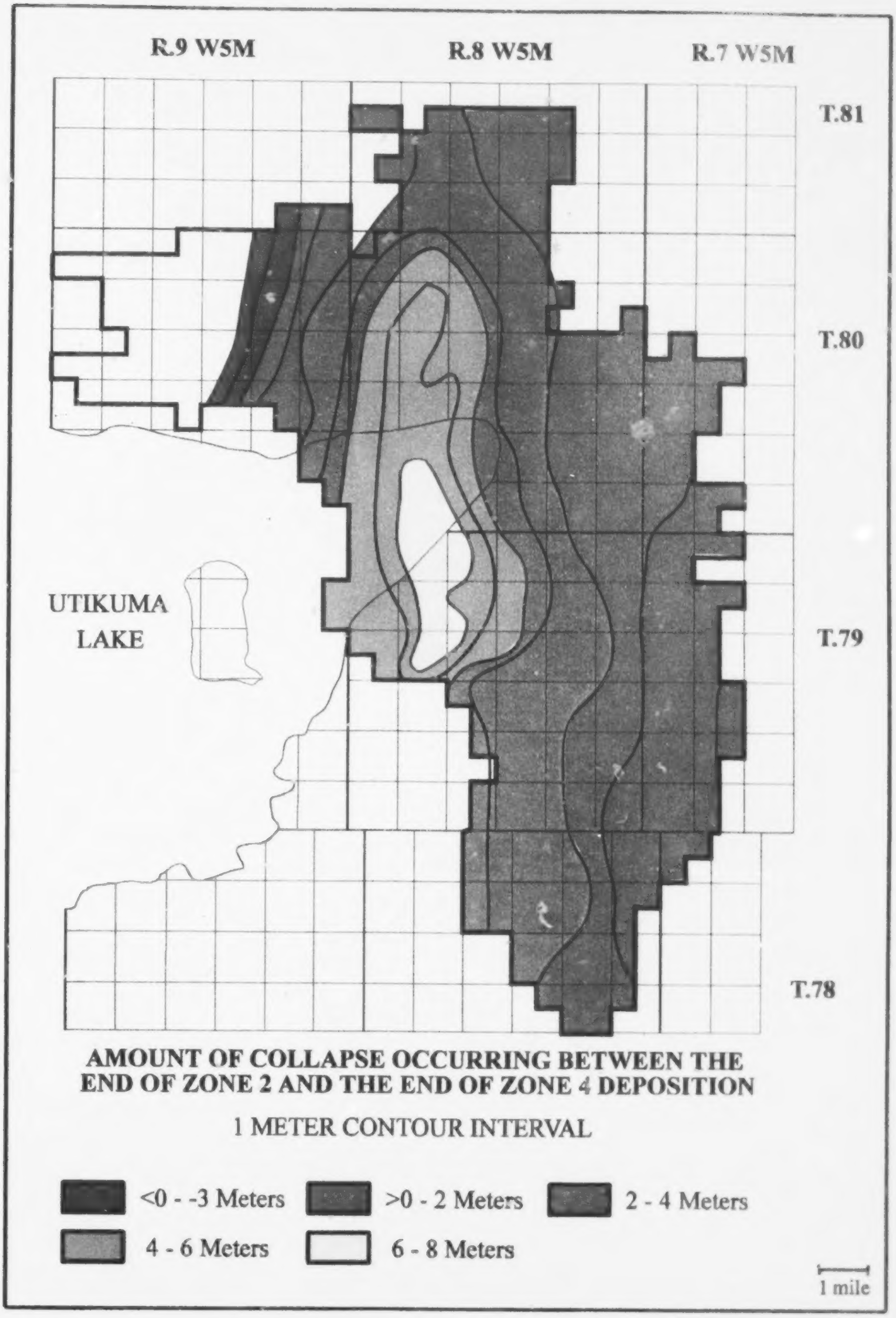


Fig. 6.10 Contour map illustrating the amount of collapse occurring between the end of Gilwood Zone 2 and the end of Gilwood Zone 4 deposition.

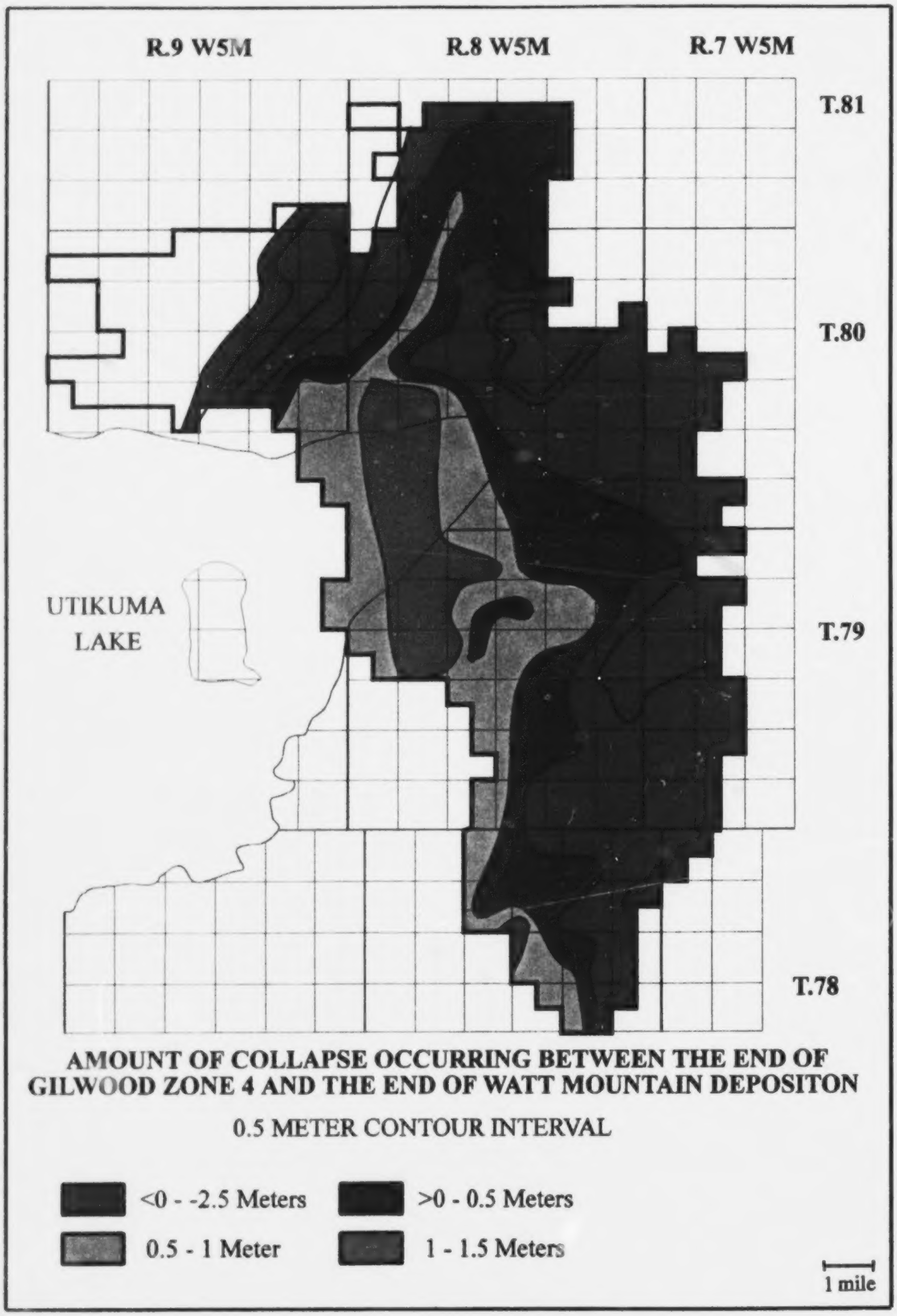

R.9 W5M
R.8 W5M
R.7 W5M
T.81
T.80
T.79
T.78
UTIKUMA
LAKE
AMOUNT OF COLLAPSE OCCURRING BETWEEN THE END OF GILWOOD ZONE 4 AND THE END OF WATT MOUNTAIN DEPOSITON
0.5 METER CONTOUR INTERVAL
<0 - -2.5 Meters
>0 - 0.5 Meters
0.5 - 1 Meter
1 - 1.5 Meters
1 mile

Fig. 6.11 Contour map illustrating the amount of collapse occurring between the end of Gilwood Zone 4 and the end of Watt Mountain deposition.

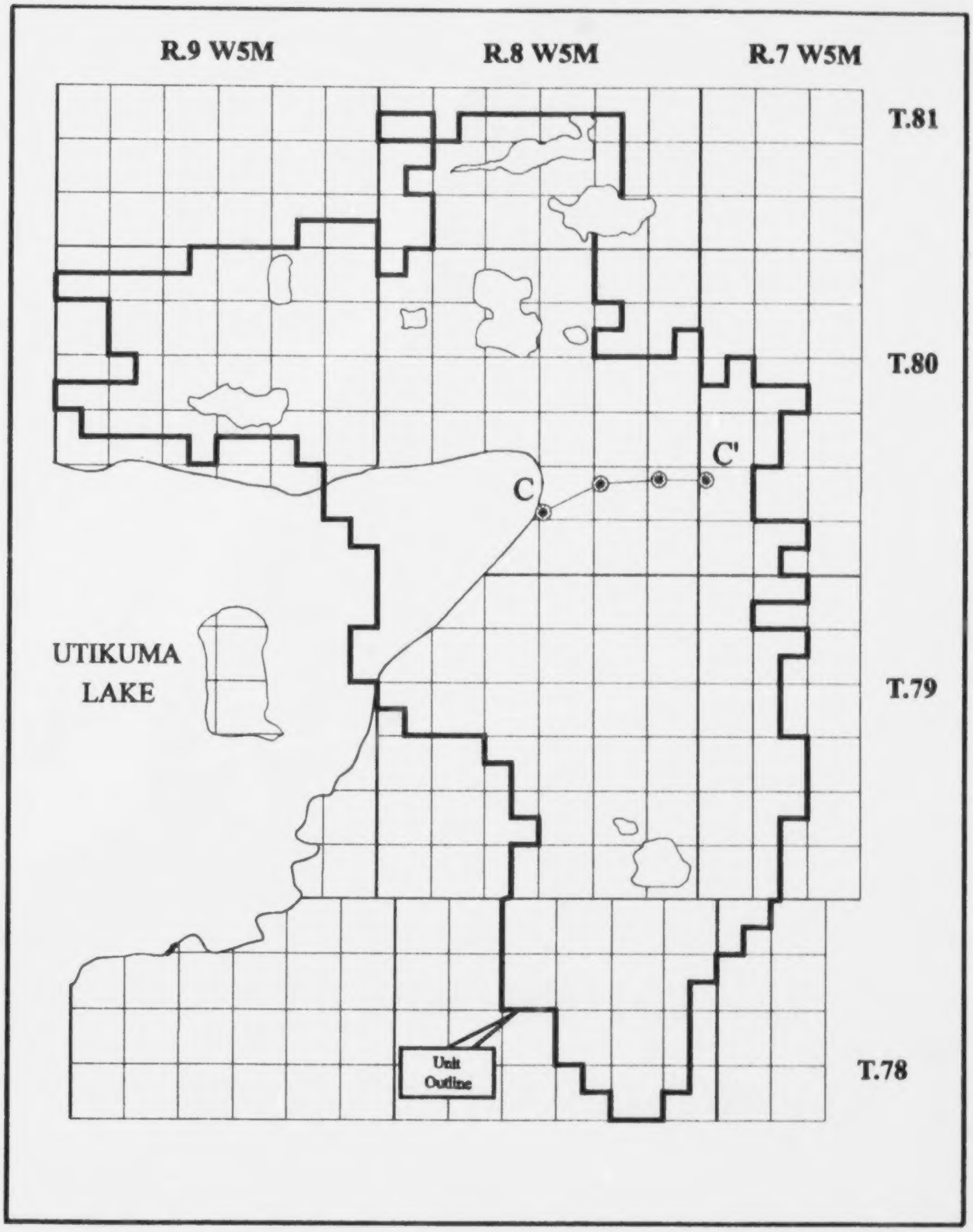


Figure 6.12 Reference map for cross sections C -C' illustrated in figures 6.13 - 6.16.

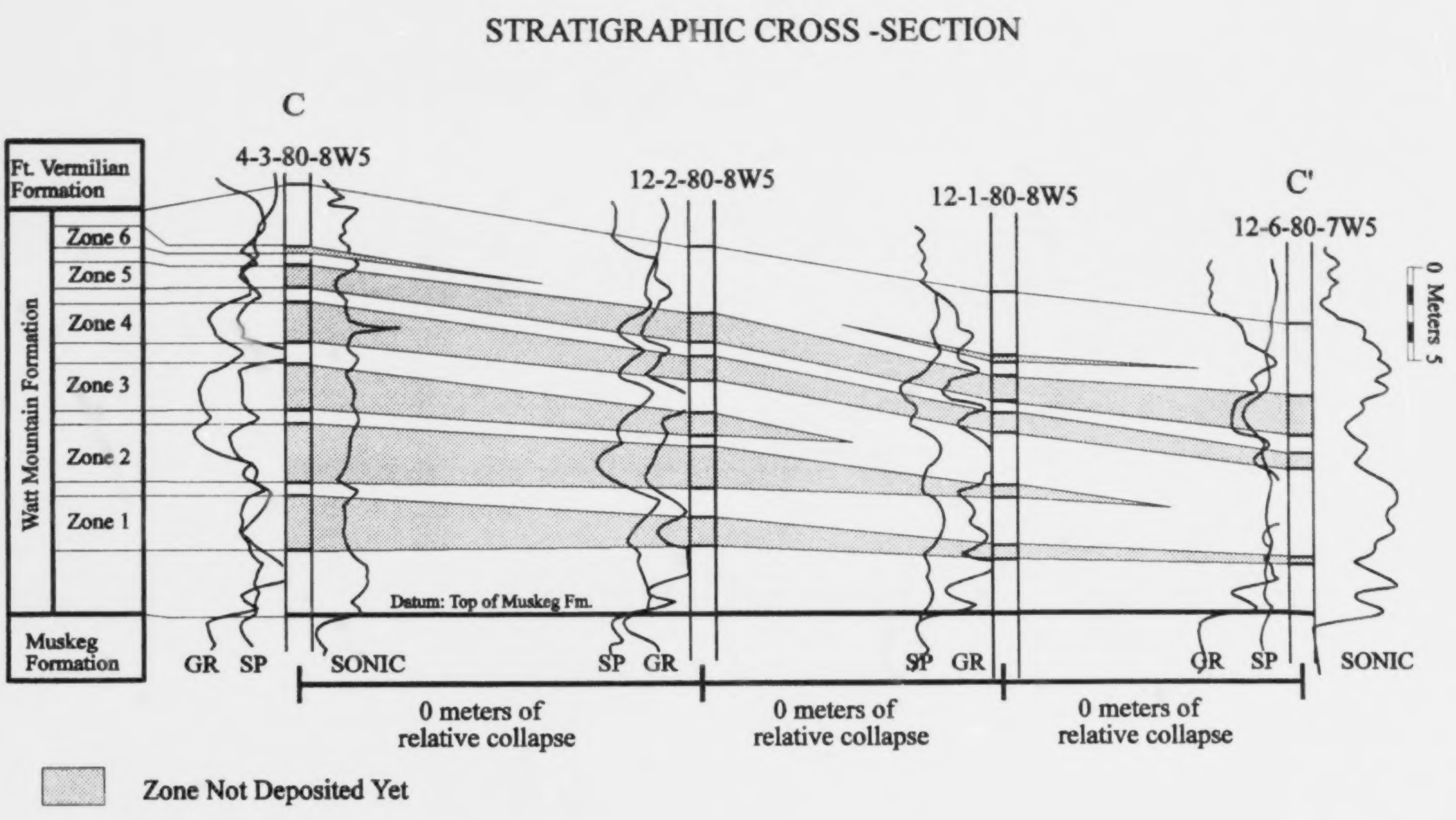


Figure 6.13 Stratigraphic cross-section C - C' illustrating the correlation of the top of the Muskeg Formation before any post Muskeg collapse or deposition of Watt Mountain Formation sediments occurred.

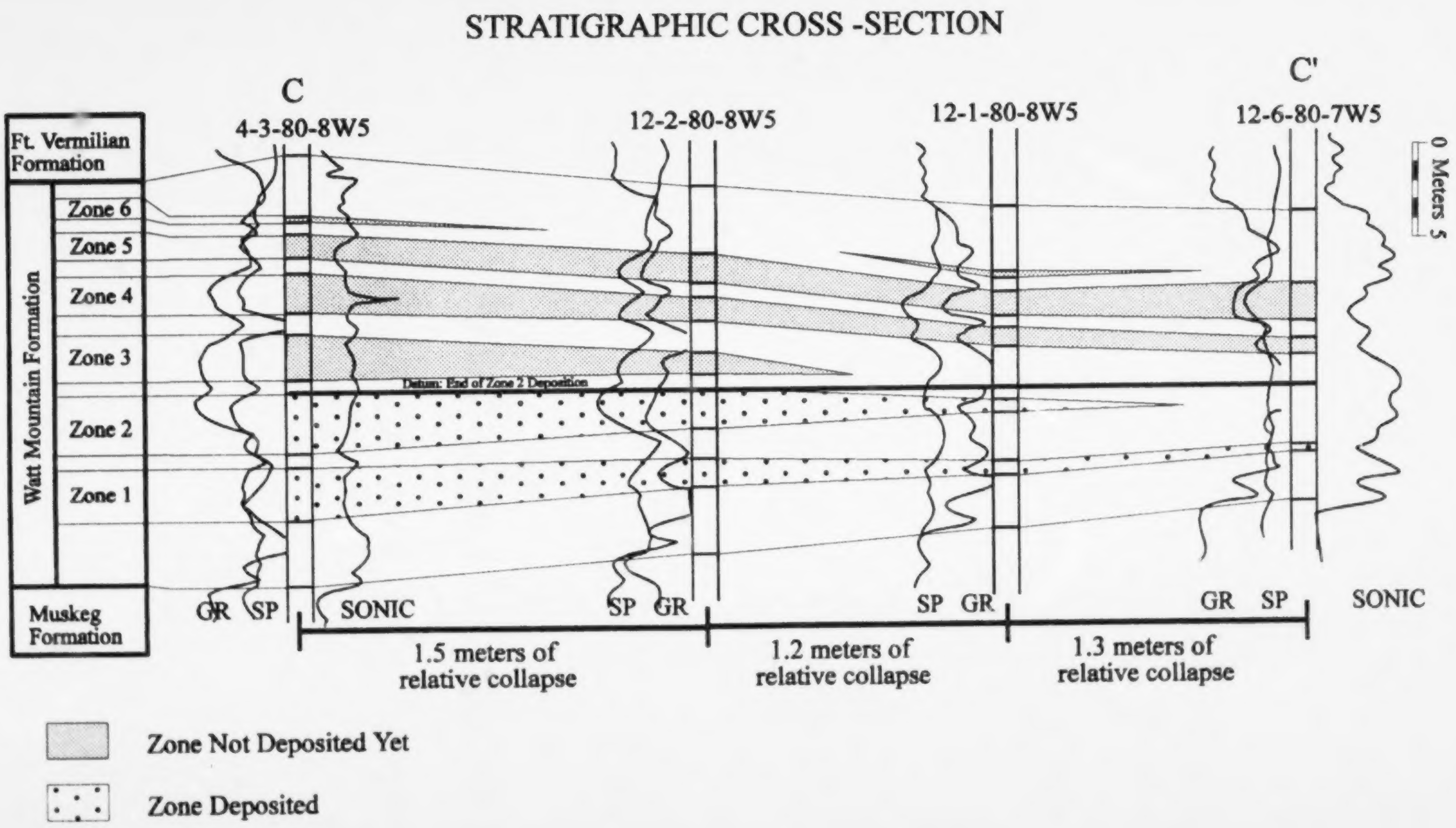


Figure 6.14 Stratigraphic cross-section illustrating the correlation of Gilwood zones and the amount of relative post Muskeg collapse between wells by the end of Gilwood zone 2 deposition.

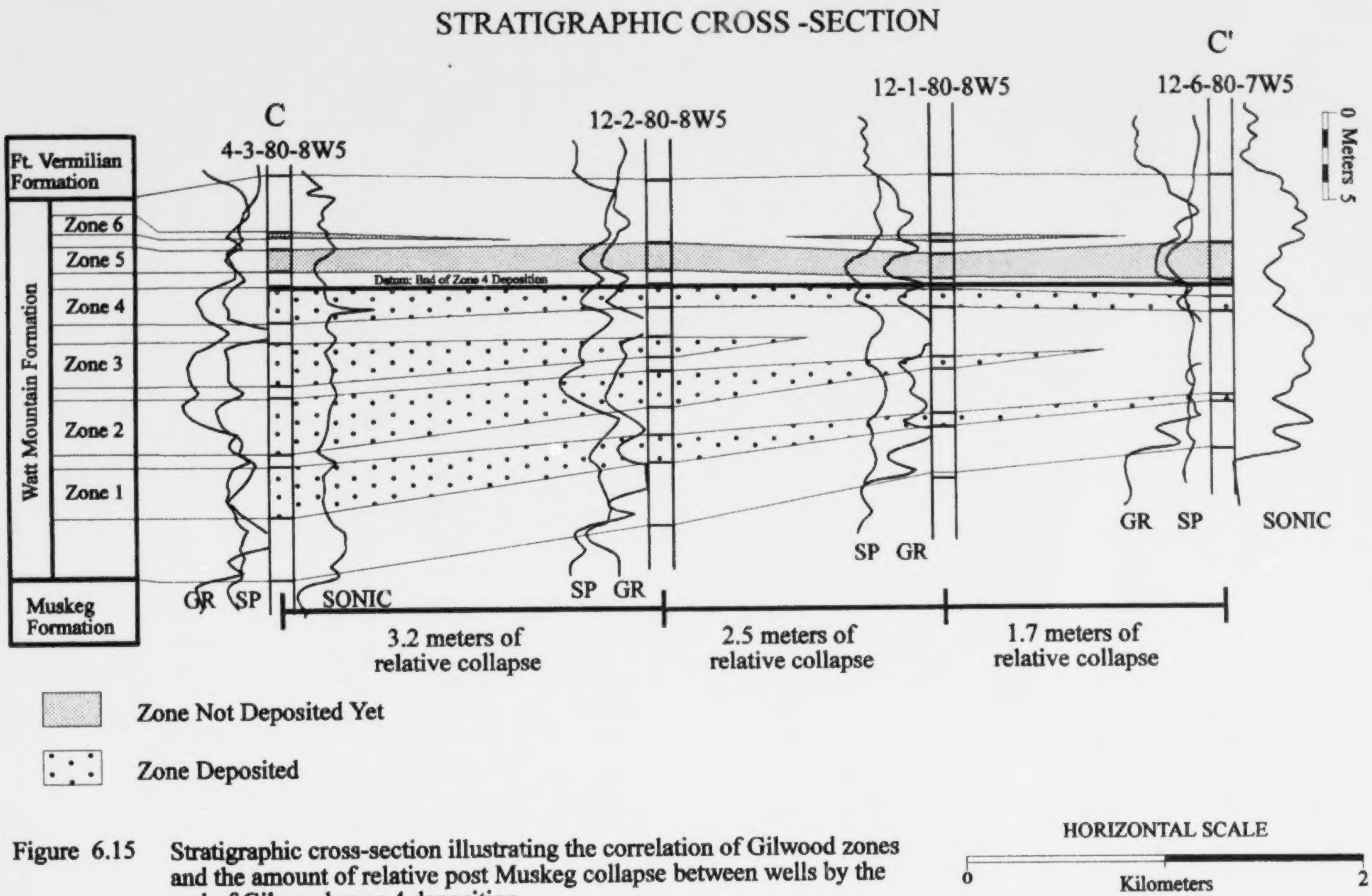
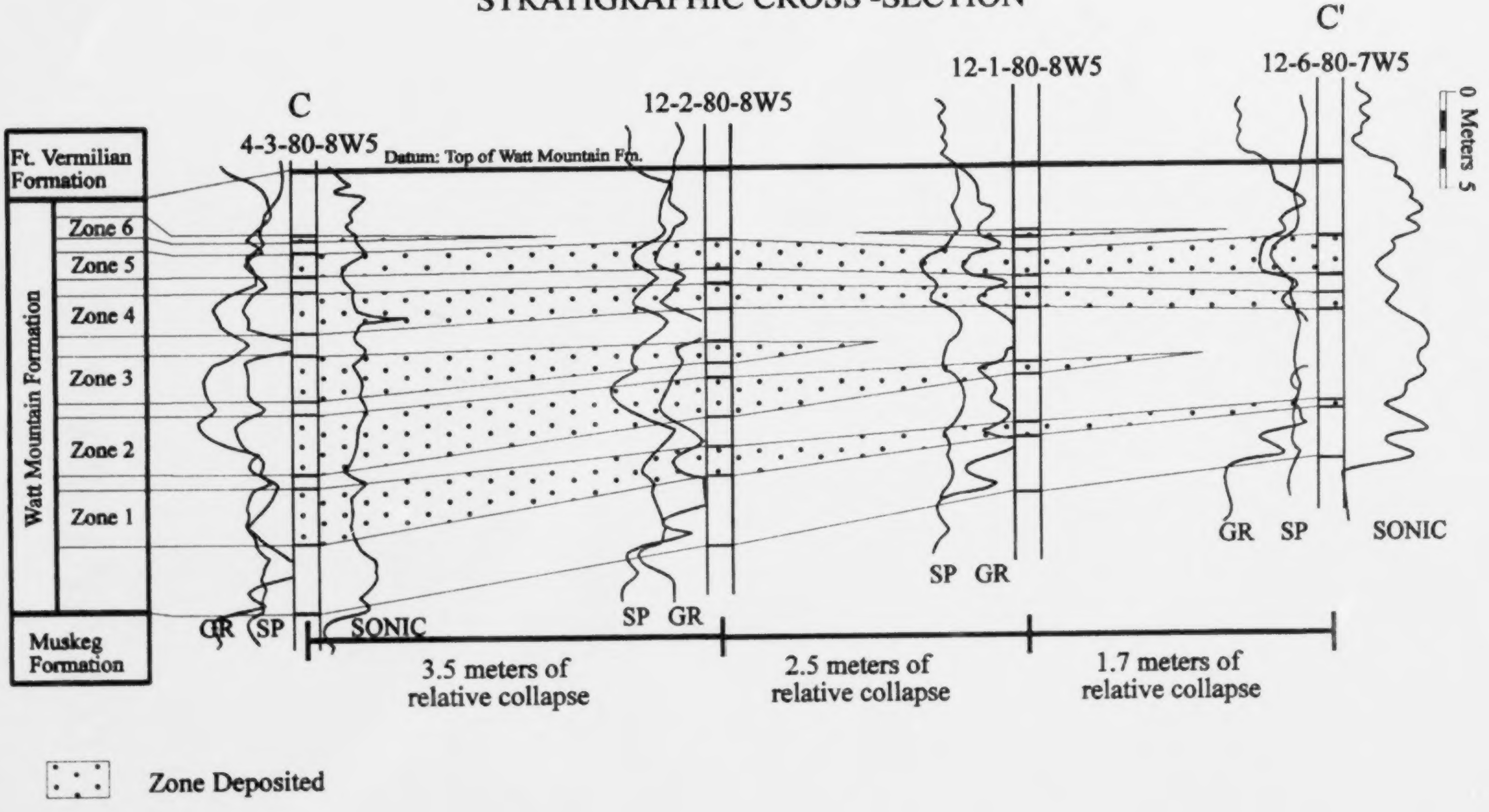


Figure 6.15 Stratigraphic cross-section illustrating the correlation of Gilwood zones and the amount of relative post Muskeg collapse between wells by the end of Gilwood zone 4 deposition.

STRATIGRAPHIC CROSS -SECTION



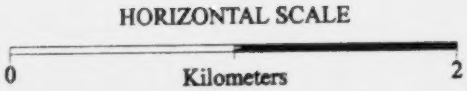


Figure 6.16 Stratigraphic cross-section illustrating the correlation of Gilwood zones and the amount of relative post Muskeg collapse between wells by the end of Watt Mountain deposition.

CHAPTER 7 DISTRIBUTION OF WATT MOUNTAIN SEDIMENTS

7.1 Introduction

The sediments in the Watt Mountain Formation in the Nipisi field have been divided into four facies associations that collectively suggested that sedimentation occurred in a lacustrine braid-delta system. Braid-delta deposits have high lateral continuity, and on a large scale they commonly produce sheet-like bodies over the length and width of the flood plain (McPherson *et al.*, 1987). In the Nipisi field, six laterally continuous sandstone-dominated zones have been identified. The paleogeographic distribution, relative sand body geometry and thickness of each zone, were found by constructing an isopach map of each (Figs. 7.1 to 7.6). Separating the six sandstone-dominated zones were mudstone deposits. These deposits were also laterally continuous; however, there were rare occurrences where these mudstones were absent, resulting in the stacking of one Gilwood zone over another.

The complexity of the vertical assemblages that make up the Watt Mountain Formation in the Nipisi field suggested that paleoenvironmental changes occurred during sedimentation of the Watt Mountain Formation. These were attributed to changes in the climate and tectonic setting, which are the two fundamental controls that influence the evolution of any basin (Reynolds *et al.*, 1989). Climate may influence the evaporation to precipitation ratio, discharge rates, and modes of sediment transport, while tectonic activity may control the basin geometry (Anadon *et al.*, 1991).

In describing the distribution of the Watt Mountain sediments an attempt was made to include the relative importance of the factors associated with the climate and tectonic controls.

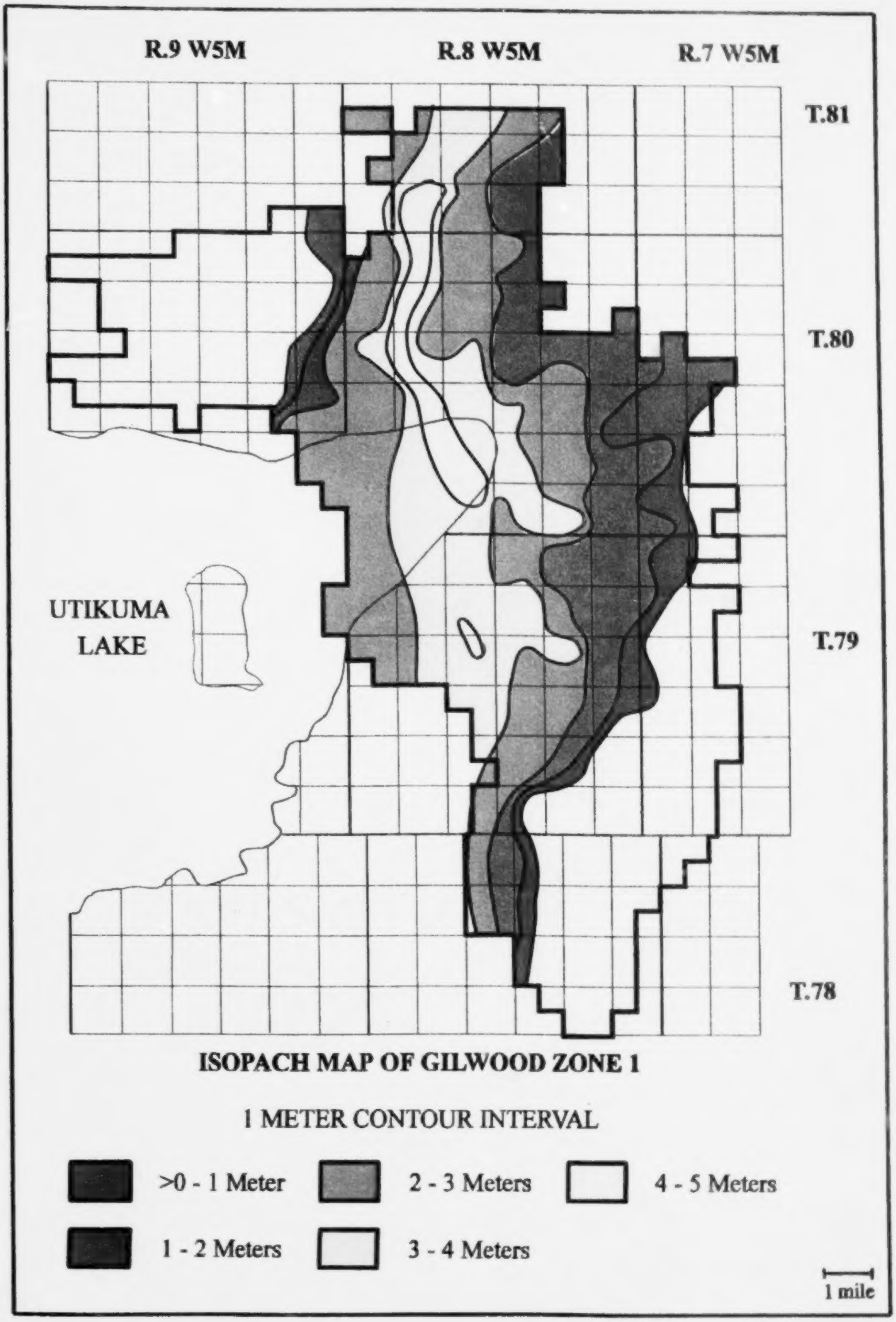


Figure 7.1 Isopach map of Gilwood Zone 1.

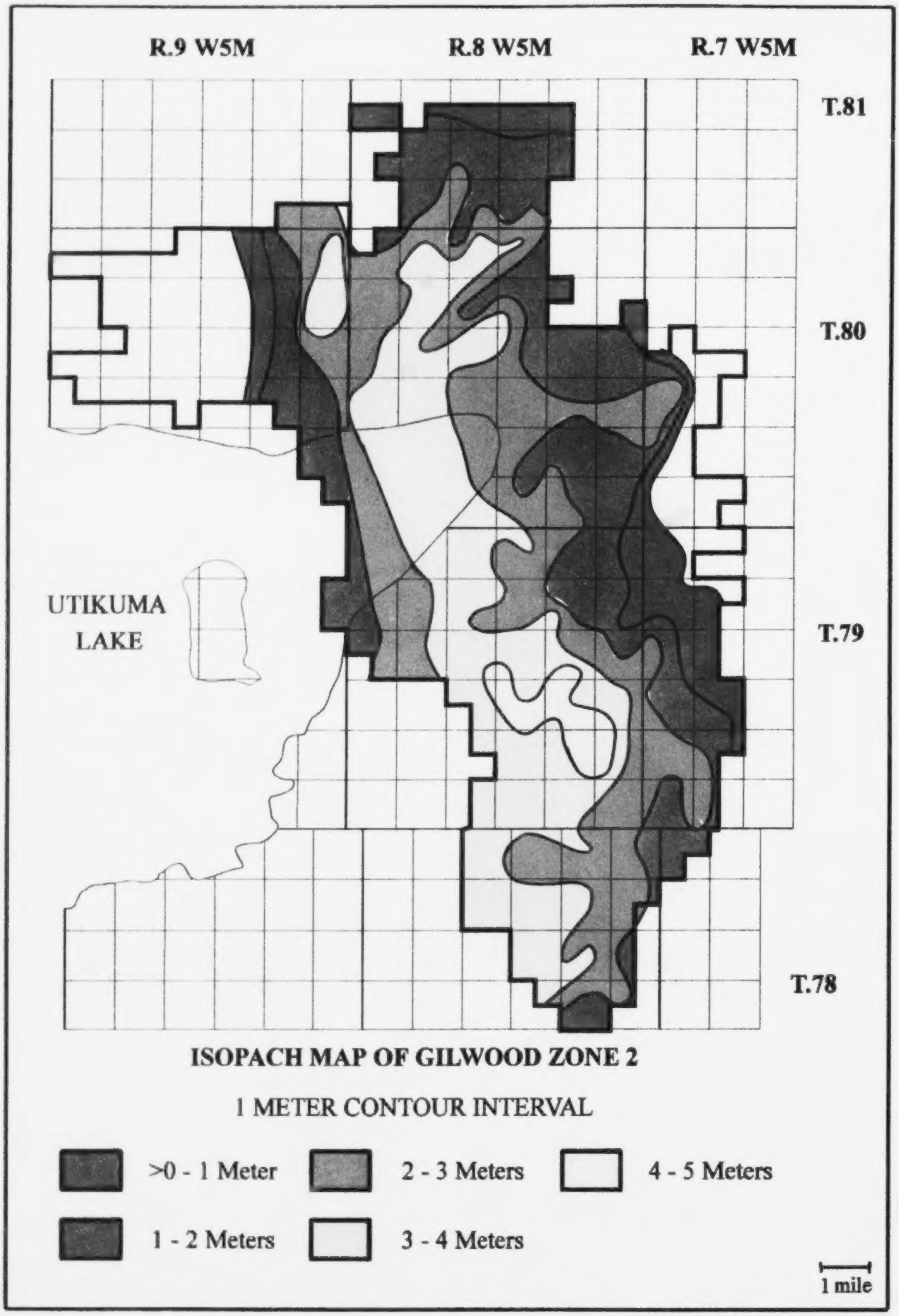


Figure 7.2 Isopach map of Gilwood Zone 2.

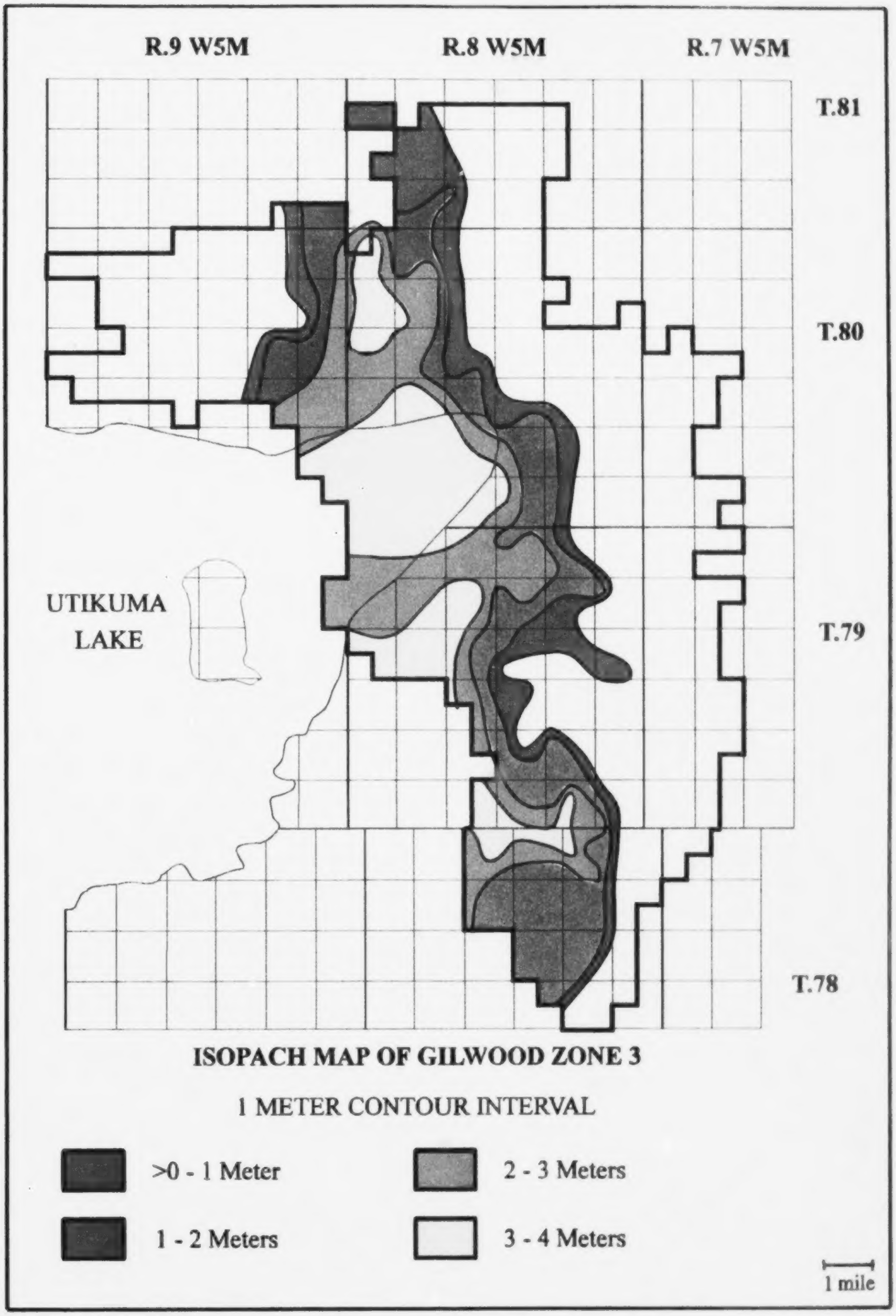


Figure 7.3 Isopach map of Gilwood Zone 3.

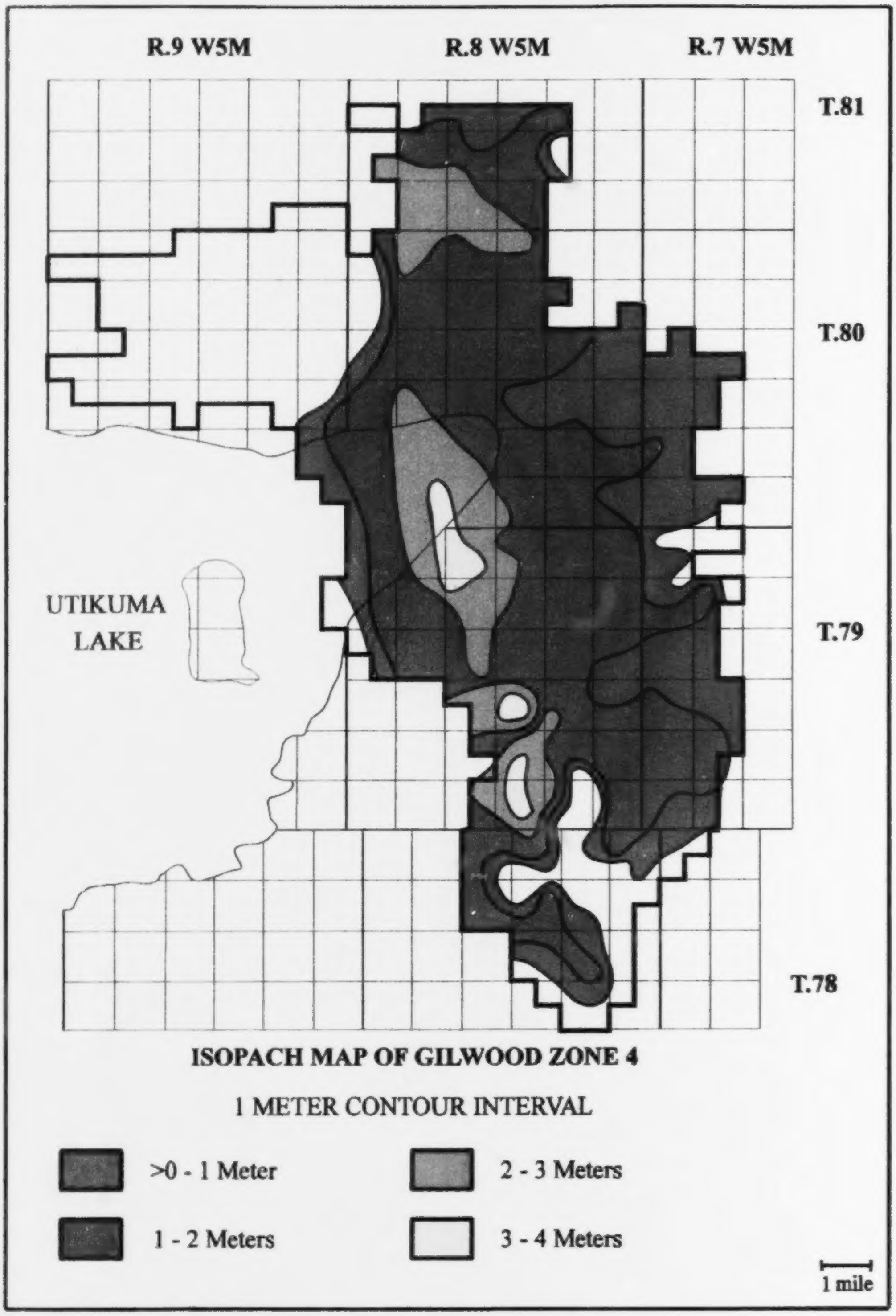


Figure 7.4 Isopach map of Gilwood Zone 4.

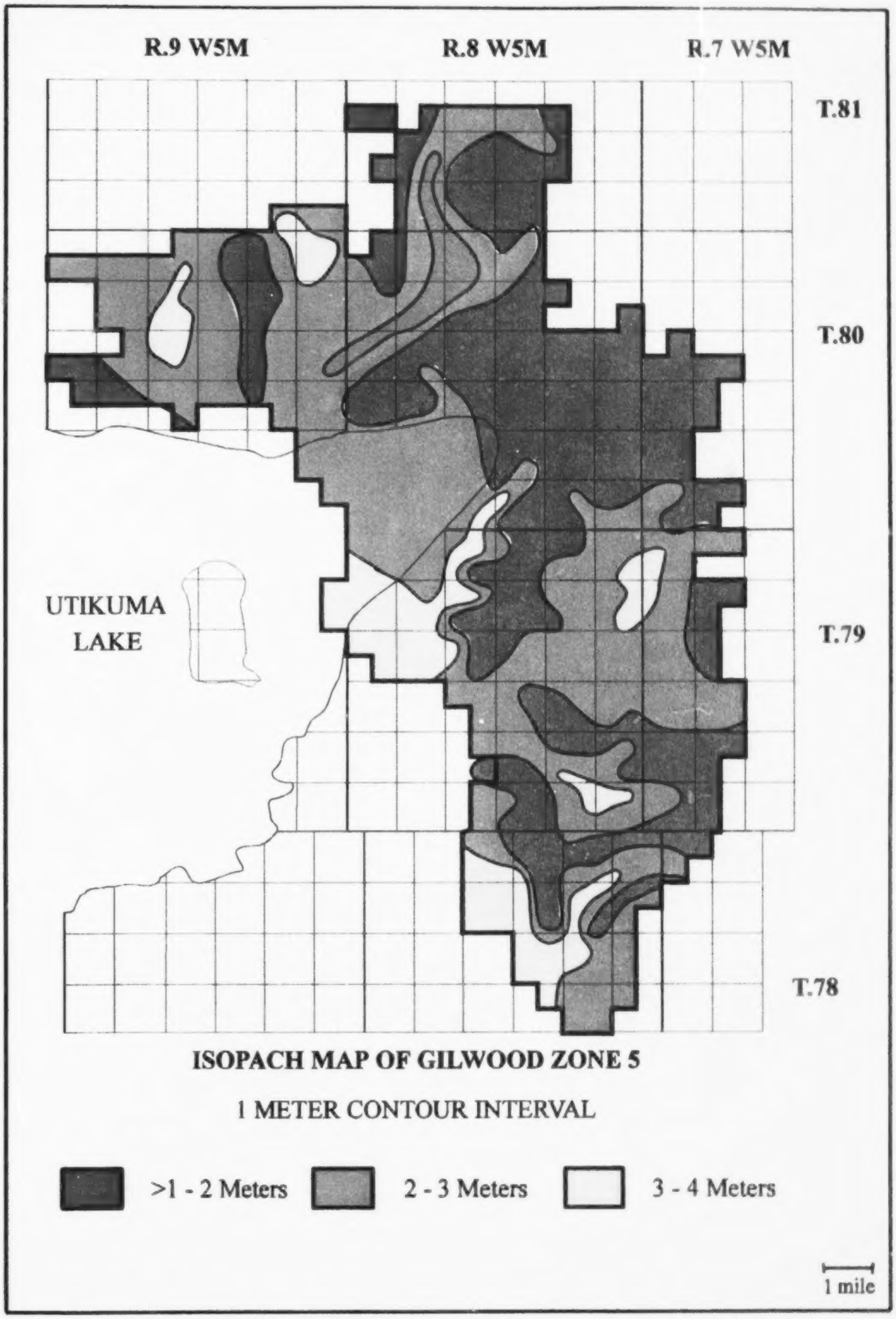


Figure 7.5 Isopach map of Gilwood Zone 5.

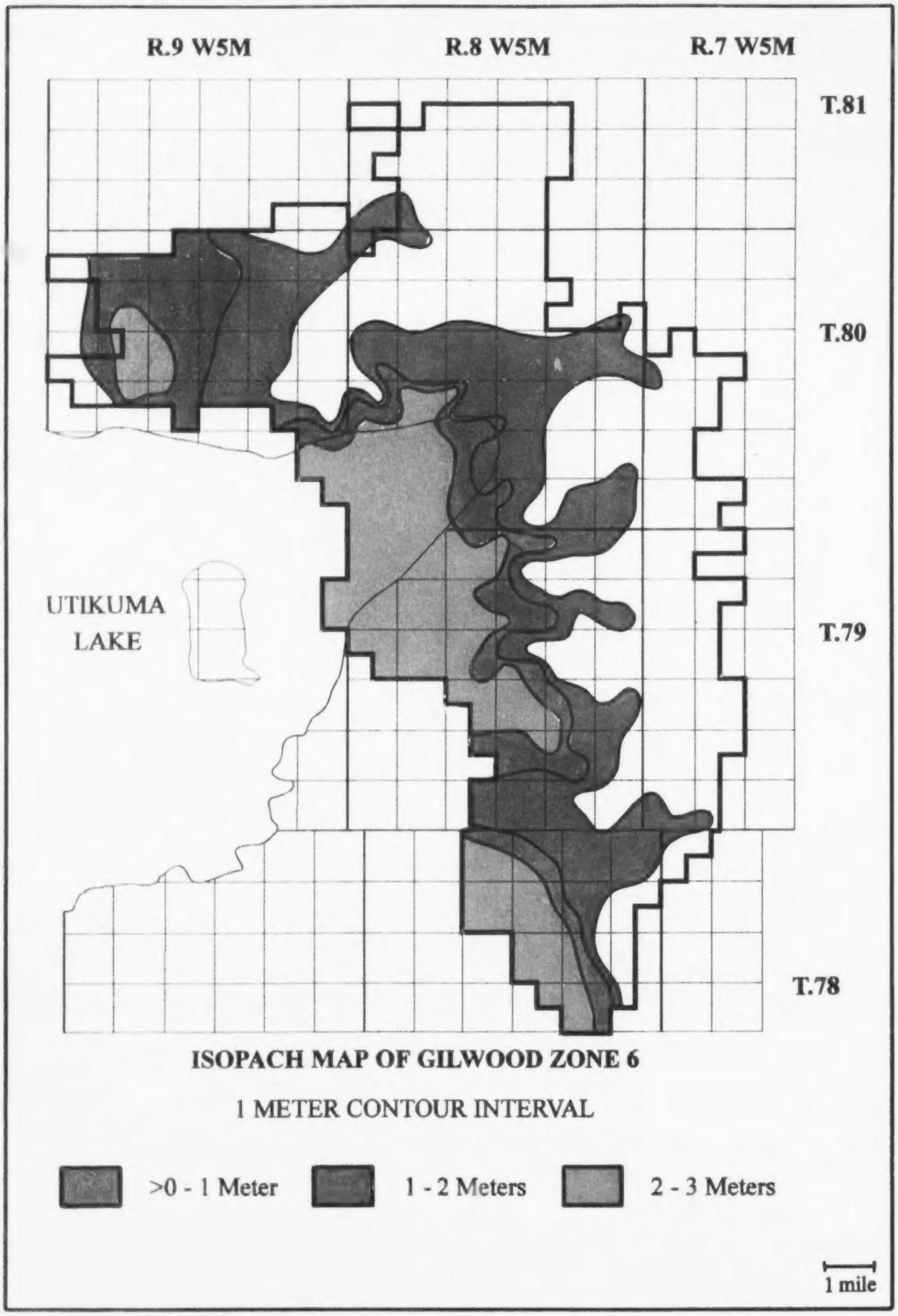


Figure 7.6 Isopach map of Gilwood Zone 6.

7.2 Distribution of the Gilwood Sandstone Zones

Each of the six Gilwood zones represent a period of high clastic input sourced from the west. Gilwood zones 1 and 3 are the most areally restricted of the six zones, suggesting that the Muskeg trough strongly influenced the distribution of these sediments by confining them as they prograded into the Nipisi area. The eastward tonguing of sediment in Gilwood zone 2, and the extension of Gilwood zone 4 out to the eastern limits of the Nipisi field, suggest some periods of Gilwood deposition were less influenced.

The differences in the areal distribution of the sandstone zones is strongly dependent on the shape of the Muskeg trough prior to deposition of the zone, and the amount of sediment deposited. Eastward progradation of a Gilwood zone deposit can only be achieved through progressive filling of the trough. Therefore, when the relief of the trough before deposition was small, less sediment was needed for the progradation across the Nipisi area than when the trough's relief was large. The lack of preservation of Gilwood zones 1 to 4 in the northwestern corner of the Nipisi field area is a result of successive deposition over this area, which resulted in the erosion of all but the upper two Gilwood zones (5 and 6).

The amount of collapse that occurred between the end of Gilwood zone 4 and the end of Watt Mountain Formation deposition was relatively minimal (Fig. 6.11). This resulted in the progradation of Gilwood zones 5 and 6 into the Nipisi area without the distribution of their sediment being significantly influenced by the Muskeg trough. Therefore, the depositional pattern and eastward progradation of these two zones across the Nipisi field was mainly controlled by the energy of the hydrologic system.

Gilwood zone 5 illustrates extensive complex tonguing emanating from a northwestern to western source with no apparent north south trend. Gilwood zone 6 is the last major episode of sandstone deposition recorded in the Watt Mountain Formation. The limited eastward progradation of this zone compared to Gilwood zone 5 suggested that the energy of this depositional system was significantly less.

7.4 Distribution of Watt Mountain Mudstones

The Watt Mountain Formation mudstones represent lacustrine deposits (Facies Association 1) that accumulated throughout the Nipisi field area during quiescent periods. These mudstones formed laterally continuous beds that effectively separate each of the Gilwood zones. During high inflow periods, sandstone deposits dominated the western areas of the Nipisi field, and mudstone accumulations were limited to areas beyond the sandstones westward progradational limits. The thicknesses of the laterally continuous mudstones that effectively separate the Gilwood zones are illustrated in Table 7.1.

Between Gilwood Zones	Thickness (meters)	
	Average	Range
1 , 2	1.3	0.0 - 2.3
2 , 3	1.1	0.0 - 3.4
3 , 4	2.0	0.3 - 3.0
4 , 5	0.9	0.0 - 1.2
5 , 6	1.1	0.6 - 2.4

Table 7.1 Thickness of mudstone units separating Gilwood zones.

A trend in the distribution of sedimentary structures in the mudstones was also observed. The mudcracks and stress cutans, interpreted to represent subaerial exposed areas, mostly developed where isopach values of the underlying Gilwood zone were small. These small isopach values were associated with areas around the fringe of the trough, which are also the first areas to become exposed when lake levels dropped.

CHAPTER 8 DEPOSITIONAL HISTORY OF THE WATT MOUNTAIN FM.

8.1 Introduction

The Elk Point sea covered the Nipisi field area during early Watt Mountain Formation deposition as suggested by the existence of a basal black shale facies (Facies 1) containing distinct marine fauna. However, most of the Watt Mountain Formation's sediments do not contain evidence to suggest deposition occurred in a marine setting. The vertical facies associations determined in Chapter 5 suggested that deposition occurred in a lacustrine braid-delta setting.

The interbedding of the Gilwood Sandstone Member with the Watt Mountain Formation mudstones clearly suggested sedimentation occurred during episodes of fluctuating paleoenvironmental conditions. These fluctuating conditions occurred in cycles that generated a recurring sequence of deposits that consisted of three stages of deposition. The first stage is a sandstone dominated deposit that makes up the Gilwood zones. This was followed by a second mudstone dominated stage that was deposited during a quiescent period, and a final stage that reflected a period of exposure. The spatial distribution of these deposits was a combined reflection of differing degrees of influence on sedimentation by the Muskeg trough, and the energy and duration of the hydrologic system. The following interpretive depositional history is a sequence of paleoenvironmental conditions that likely existed during Watt Mountain deposition. It was determined by integrating the distribution of facies associations and the depositional patterns of the Gilwood zones and Watt Mountain Formation mudstones.

8.2 Depositional History

The lacustrine braid-delta setting in the Nipisi area was initiated by salt solution collapse in the Muskeg Formation in early Watt Mountain deposition. This developed a north-south trending trough in the center of the Nipisi field which, during a regressive phase in the Elk Point sea, formed an isolated body of water, or lake. After formation of this lake, changes occurred in the type of sediment being deposited. In the Nipisi area, the change was from black shale containing a distinct marine fauna to a variegated mudstone containing fish that were believed to have proliferated under fresh to brackish conditions. However, the conditions for the survival of these fish deteriorated as the ratio of evaporation to inflow increased. This resulted in a progressive lowering of the lake and exposure of previously submerged areas, as indicated by the presence of stress cutans and mud cracks in the mudstones that underlie Gilwood zone 1.

Gilwood zone 1 represented the first major influx of coarse-grained sediment into the Nipisi field area, and the beginning of the first depositional cycle in the Watt Mountain Formation. The restricted sand body geometry of the first stage of deposition (Gilwood zone 1) was attributed to significant relief in the trough which limited the progradation of braided channels. Changes in the paleoenvironmental conditions terminated Gilwood zone 1 deposition and initiated stage 2, which was the deposition of mudstones throughout the Nipisi area. This rapid change in the paleoenvironmental conditions likely caused a rapid demise of the fish living in the lake, since their remains were only located in the lower 0.3 m of this mudstone unit. The existence of a high evaporation to inflow ratio progressed the cycle of sedimentation into stage three, where continual drops in lake levels resulted in the development of soils around the fringes of the lake. Most modern lakes are bounded by subaerial erosion surfaces with some degree of soil development (Picard and High, 1972). The existence of the fresh water carbonates located in the center of the trough indicated that some areas remained submerged. It is unknown whether these submerged areas were localized ponds or the continued presence of a very shallow lake in the center of the trough.

Gilwood zone 2 was the beginning of a second depositional cycle. This second cycle was very similar to the first. However, a lower relief in parts of the trough, resulted in stage 1 deposits (Gilwood zone 2) to be more widespread and extend farther southeastward than Gilwood zone 1 stage 1 deposits. Stage 2 and 3 deposits of this cycle were very similar to cycle one. Abundant fish remains in the first 0.3 m of the overlying mudstone indicated rapid deterioration of favorable living conditions, and a lowered lake level again resulted in the exposure of mudstones and the development of soils in the fringes of the Nipisi field area.

Prior to the beginning of the third depositional cycle there was a significant event of salt solution collapse in the Muskeg Formation that resulted in an extremely limited aerial distribution of Gilwood zone 3 (Fig 7.3). The northwestern to western sourced sediment of Gilwood zone 3 was confined to a narrow north-south-trending band that followed along the axis of the trough. The existence of some sandy mudstone zones in stage 2 deposits of this depositional cycle suggests that smaller streams continued to supply sediment to the lake. However, the water conditions still deteriorated significantly enough to make the lake waters unfavorable for the survival of fish. A result of evaporation exceeding inflow was the development of soils around the fringing areas of the Nipisi field during stage 3 of this cycle.

Before the beginning of cycle 4 deposition there was only minor salt solution collapse. Therefore, the significant collapse occurring before cycle 3 is almost directly related to the amount of collapse illustrated in Figure 6.10, which is the amount of collapse occurring between the end of Gilwood zone 2 and the end of Gilwood zone 4 deposition. The limited relief occurring before cycle 4 restricted the amount of excess thickening that normally occurred along the axis of the trough, and consequently a more widespread distribution of sandstones developed. Stage 2 was very short resulting in the deposition of a thin mudstone. Although stage 2 was dominated by mudstones, the significant number of sandy mudstone zones suggests a continued presence of inflow into the lacustrine basin. The lack of stress cutans in these mudstone deposits signifies that lake levels did not drop enough to cause submerged areas to become exposed for soil development (stage 3).

The fifth cycle of deposition in the Watt Mountain Formation began with the deposition of Gilwood zone 5. The distribution of this zone (Fig. 7.4), suggests that zone 5 deposition was not influenced by the trough . The lack of major relief in the trough removed one of the major depositional controls imposed on clastic sediments entering the lacustrine area. Sandstones were deposited on a slightly sloped braid-delta plain, forming a broad sheet-like sandstone with thicker, complex eastward-extending tongues. Beginning at the deposition of zone 5, there was a significant change in the depositional setting of the Nipisi field area. Although stage 2 mudstones developed, they had a blocky grayish-green to olive-gray colour, which was distinctly different from the stratigraphically lower mudstone deposits that were primarily variegated red and green in colour. This difference in colour may be associated with a change from a primarily subaerial oxidizing environment, or a subaqueous one with input of continental oxidized sediments, to a primarily subaqueous environment (Martini *et al.*, 1991). Very little collapse occurred between the beginning of Gilwood zone 4 and the end of Watt Mountain deposition (Fig. 6.11). Gilwood zone 6 is the last major clastic pulse of sedimentation reflected in the Watt Mountain Formation, and it's depositional pattern reflects the lack of depositional control imposed by the trough (Fig. 7.6).

CHAPTER 9 SUMMARY AND CONCLUSIONS

The Middle Devonian Watt Mountain Formation within the Nipisi oil field area, consists of a complex succession of lacustrine braid-delta deposits. This paleoenvironmental interpretation was based on the existence of four recurring facies associations: (1) lacustrine deposits, (2) marginal lacustrine deposits, (3) interdistributary deposits, and (4) channel deposits. The complex succession of deposits was subdivided into six cycles of deposition, which record the progradation and abandonment of lacustrine braid-delta deposits. An idealized cycle is internally characterized by three stages of deposition. The first or lower stage is dominated by sandstone deposits, followed by a mudstone dominated middle stage, and an upper stage which reflects deposits exhibiting evidence of subaerial exposure.

The stage one sandstone deposits consist of channel and marginal lacustrine deposits which prograded across a low gradient braid-delta plain during periods of sandstone influx. These periods of influx have been attributed to tectonic activity associated with the Peace River Arch. Channel sandstone deposits prograded eastward, away from the Arch, forming laterally continuous sheets of sandstone across the Nipisi area. In the distal areas beyond the sandstone progradational limits, lacustrine mudstone deposits were also being accumulated. However, the stage two lacustrine mudstone deposits which separated each of the Gilwood sandstone zones dominantly accumulated in the periods between sandstone influx.

The distribution of braid-delta deposits was strongly controlled by the shape of the Muskeg trough, which was a depression that developed in the center of the Nipisi field area through dissolution of salts within the underlying Muskeg Formation. Dissolution related subsidence occurred prior to and during Watt Mountain deposition, modifying the amount of relief in the Muskeg trough. The effect of this relief on

Gilwood sandstone zone deposition is reflected in the depositional patterns of these deposits. Gilwood sandstone zone deposits strongly influenced by the trough were restricted in their areal extent, while zones less influenced had wider areal distributions because of their ability to freely prograde across the Nipisi field area. The understanding of the paleoenvironment and depositional history of Watt Mountain Formation sediments in the Nipisi field area provided information that was essential in determining that Nipisi oil is distributed within a layered reservoir. The knowledge that each of these layers has different reservoir characteristics and areal distribution will aid in developing exploitation strategies.

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APPENDIX

LEGEND FOR APPENDIX

LITHOLOGY

- ⛆ Sandstone
- ⛆ Siltstone
- ▤ Mudstone
- ▨ Anhydrite
- ⛆ Silty Sandstone
- ⛆ Sandy Silt
- ▤ Sandy Mudstone
- ▩ Breccia
- ⛆ Muddy Sandstone
- ▤ Muddy Silt
- ⛆ Silty Mudstone
- ⊠ Missing Core

Lithologic Modifiers

- ⋯ Sandy
- ⋯ Silty
- - - - Muddy
- ▲▼▲ Mud Clasts
- ▪•▪•▪ Small Mud Clasts
- Mc Micaceous
- Fld Feldspar Clasts
- Py Pyrite
- Palsl Paleosol
- ▲▼▲▼ Brecciated
- oooo Pebble Horizon
- ♣ Scattered Limestone
- ♣ Dense Limestone

Physical Structures

- ≋ Climbing Ripples
- ◡ Trough Cross Bedding
- /// High Angle Lamination
- ≡ Horizontal Lamination
- xxxxxx Minor Cemented Horizon
- ⌒ Current Ripples
- * Massive Bedding
- ═ Low Angle Lamination
- ⋮ Grading, fining upward
- ⋮ Grading, coarsening upward
- ∿∿ Stylolites
- Ⓢ Stress Cutans
- Slks Slickensides
- @ Churned Bedding

Fossils

- ▽ Brachiopod
- ⓣ Fish Scales
- ⊂⊃ Fish Bone
- ⋈ Fish Remains

Relative Porosity

▩	Poor 4 - <9%
░	Fair 9 - <14%
▓	Good 14 - <19%
█	Excellent >19%

Contact Type

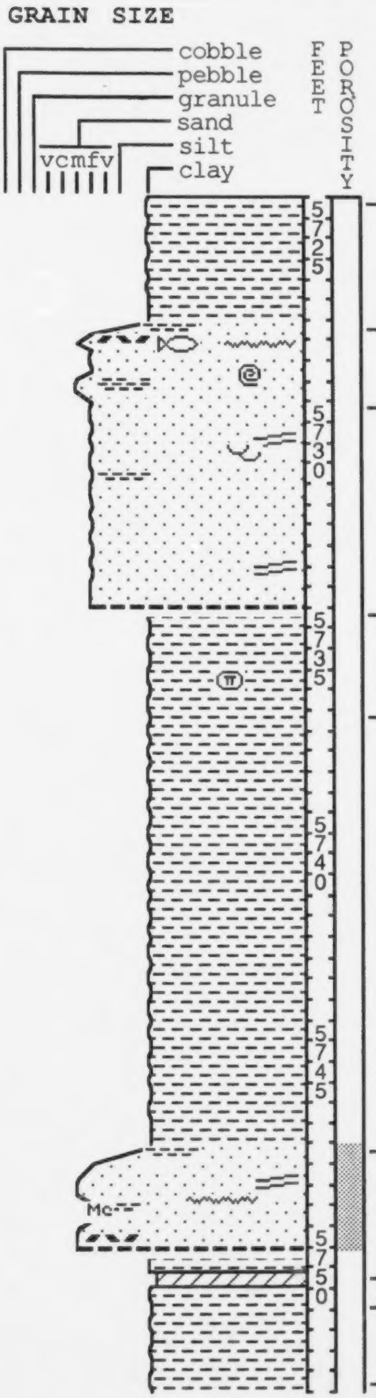
- ── Sharp
- ━━ Scoured
- - - - - Uncertain
- ∿∿∿ Undulating

ABBREVIATIONS USED IN CORE DESCRIPTIONS

abnt	abundant
bcmg	becoming
bdng	bedding
bds	beds
blk	black
blky	blocky
brn	brown
btm	bottom
calc	calcareous
cg	coarse grain
cgs	coarse grains
cmtd	cemented
conv	convoluted
disc	discontinuous
dk	dark
drb	dark reddish brown
dsky	dusky
feld	feldspar
fg	fine grain
fltg	floating
fsl	fissile
fract	fracture
fnt	faint
grd	grade
grn	green
grns	grains
grysh	grayish
hzntl	horizontal
intb	interbedded
intlam	interlaminated
ip	in part
lam	laminations
lamd	laminated
lrg	large
mass	massive
md	mud
mdst	mudstone
mdy	muddy
mg	medium grain
mnr	minor
msng	missing
mxd	mixed
ol	olive
pbl	pebbles
pl	pale
psbl	possible
pyb	pale yellowish brown
rdsh	reddish
rmdr	remainder
seqc	sequence
sh	shale
slks	slickensides
slst	siltstone
sl	slightly
sndy	sandy
srtd	sorted
ss	sandstone
sty	stylolites
thnly	thinly
thru	throughout
tr	trace
twds	towards
vfg	very fine grain
v	very
vp	very poor
wd	wood
wxy	waxy
ylsh	yellowish

Pan Am A-1

2-17-78-7w5 Core mostly rubble



dsky grn hrd blky sh

base 19cm is conv - low angle xbdng w/ mud clasts and flasers,scat cg feld clasts, 16cm of fg conv well sorted ss grad from below, upper 17cm is intbd ss&sh cm scale, ss bds fin up, base cg-peb upper bds fg, fish plates present in upper unit

fg ss w/ abnt mic thru, bdng varies thru from low > xbdng, pos trough, occas mud lams, generally well sorted

grysh grn hrd - med blky sh, bot contact w/ drb is gradational for 15cm , few fish scales at start of pure grysh grn sh

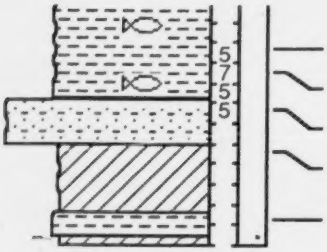
drb hrd blky sh , bot 10cm is grysh grn hrd blky sh

mainly low > xbdd ss, multiple fin up seq, crsr cmtd bands, shly to top, shly lams are mic

tan anhy sh hrd blky

drb hrd blky sh

dsky grn hrd blky fsl ip sh w/ fish plates



mixed finely wormy texture drb & grysh grn hrd blky sh

pl grn hrd blky sh, few plates @ base

fg pl grn shly ss w/ few horz blk & pl grn mud bds & lams

tan anhy

blk hrd fis sh,

Pan Am D1 Nipisi

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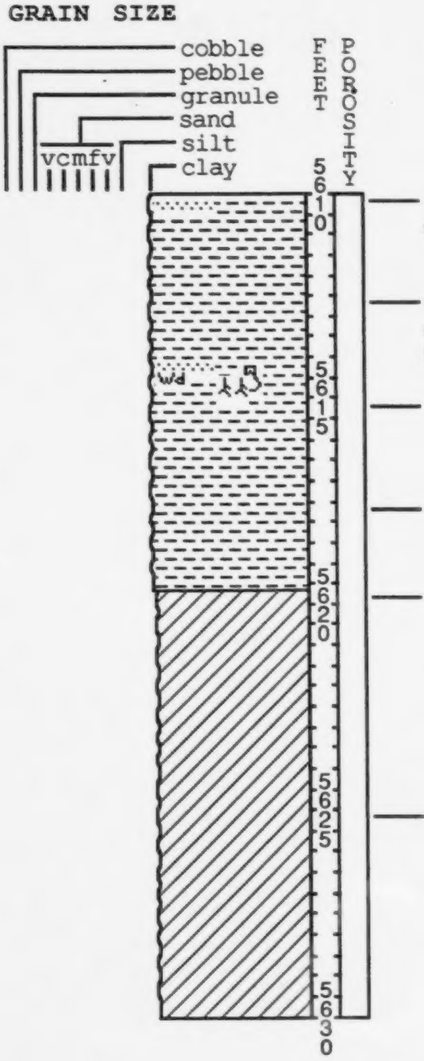

hrd blky sh, base is 15cm drb brec, upper part is slty-sndy hrd blky pl grn sh

mostly broken up rubble cm scale, psbl roots or mud cracks @ base, ostracod, sh is mainly grysh grn sh, very fsl,

mixed brn & pl grn sh hrd blky

drb hrd blky sh, basal 15cm is pl grn,

vgtd anhy, drb-rd, gry, grysh grn,blk-drk brn,

tan anhy

Shell et al Nipisi

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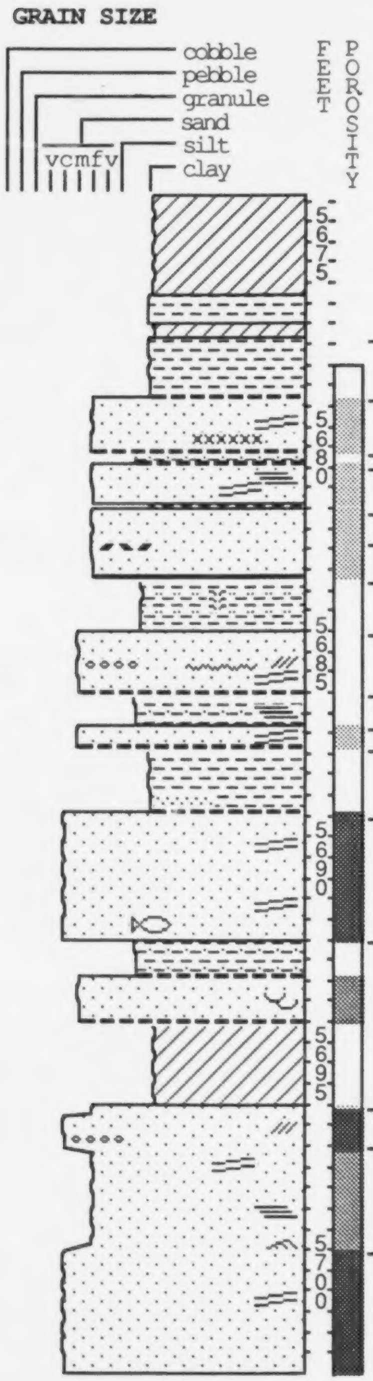


grysh grn hrd blky sh

pyb fg ss low > bdng, anhy nod 2x1cm near top, bot 6cm completely cmtd

grysh grn sndy sh hrd blky

pyb fg ss, low angle bdng w/ few mud lams

pyb fg ss , mainly low angle bdng

2cm of scat mud clasts

dsky grn slty sh, hrd mass, some dewatering struc.

pyb mainly mg ss, scat fg bds, one peb layer 2 in w/ minor scour

pl grn slty sh, less slty toward top, horz bdng @ base

pyb mg ss, low ang bdng. few mud clasts

grysh grn hrd blky sh, basal 6 in is sandy and contains a 2 in cg cmnt bed with low angle bdng.

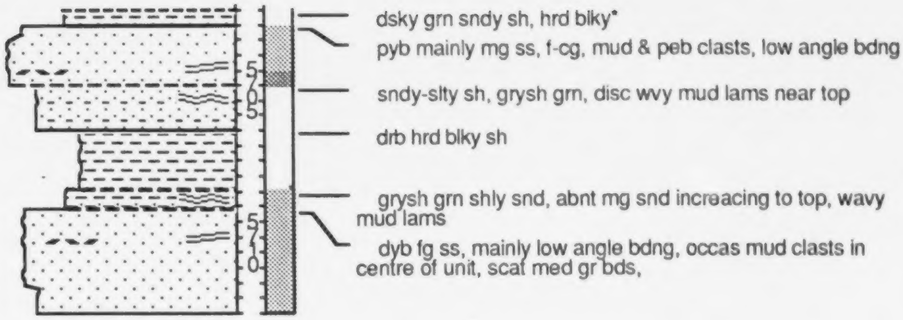
dyb cg ss, mainly low ang bdng, few high angle, fish plate

grysh grn sndy sh, abnt peb of fld & qtz 1x1cm

dyb cg- peb ss, high angle bdng, mud clast 2x2cm, more pebbly @ base

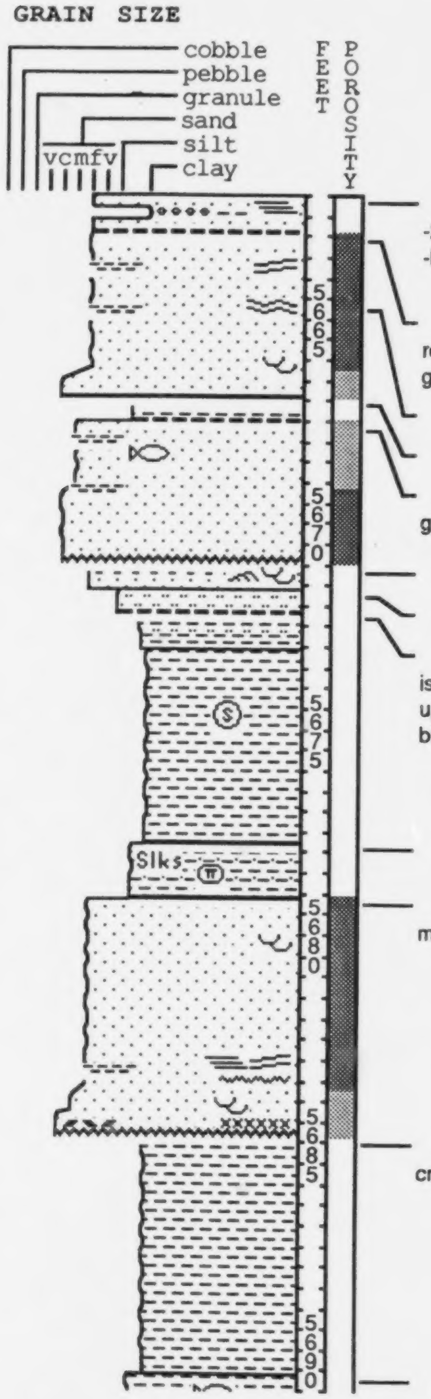
top of fin up unit, dyb fg ss, rippled base, horz bdng mid, low - high angle bdng at top, few crsr gr snd bds in low angle unit

dyb cg ss w/ abnt peb, low angle bdng


dsky grn sndy sh, hrd blky*
pyb mainly mg ss, f-cg, mud & peb clasts, low angle bdng
sndy-slty sh, grysh grn, disc wvy mud lams near top
drb hrd blky sh
grysh grn shly snd, abnt mg snd increacing to top, wavy mud lams
dyb fg ss, mainly low angle bdng, occas mud clasts in centre of unit, scat med gr bds,
5705
5710

Shell et al Nipisi

12-24-78-8w5



- upper 18cm intb cg-peb ss w/ 1-2cm sh bds.
-2cm of fg mas well sort ss
-basal 5 cm is sh fg ss w/ wavy- rip, and dewatering struc,

pyb ss, two small fin up seq @ base w/ in 14cm cg-mud. rest of unit is uf-lm gs, lower trough & upper low> bdng, good sorting.

5cm of fg shly ss w/ wvy bdng

dsky grn sndy sh, horz wavy bdng

dyb, f-cg ss, gen fin up but cg - peb through, great var in gs, fish plates, bdng hard to discern trough?

shly fg ss, grysh grn, pos rip @ base, trough @ top.

pl grn mas sltst

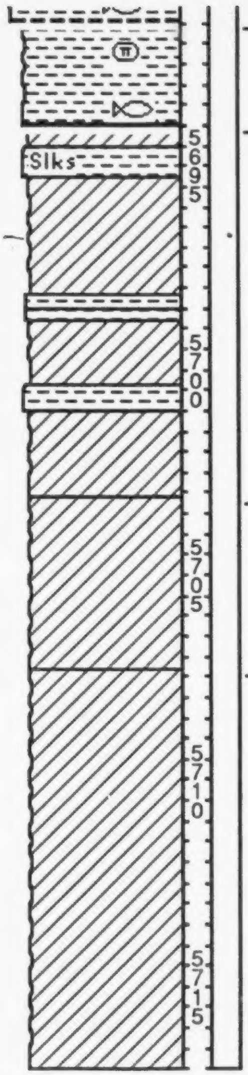
drb mod fsl sh, bot 30 cm is mot drb grsh grn w/ slks, mid is broken
up rubble w/ microslks. upper 30 cm is more slty & sndy hrd blky

grysh grn slty-sndy sh, few slks, pale grn sh bot 10 cm

pyb ss c-fg, fin up, cmtd cg @ base, few mud lams above minor scour,

drb hrd blky sh, core box 8 is complete rubble, upper 35 cm of unit is pale green hrd blky sh (not broken)

grysh ol slty sh, fish plates



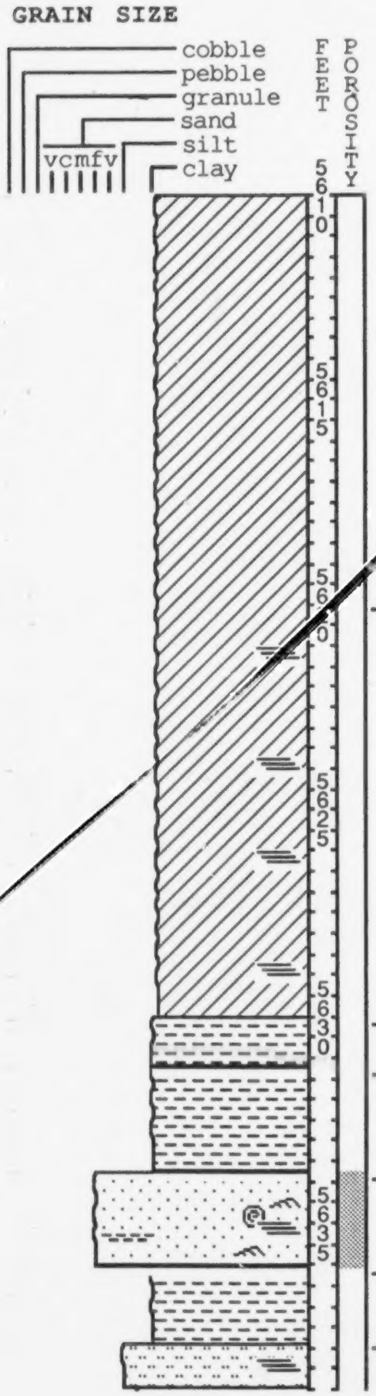
dsky red v fsl sh, sndy ip, plates, upper 15 cm is pl grn mod fsl sh.

intb blk, ol gry , grysh ol fis sh w/ tan anhy sh

tan muddy anhy

solid anhy for rest of core

Mobil SW Nipisi Mobil SW NIPISI
10-26-78-8w5



Started logging here,

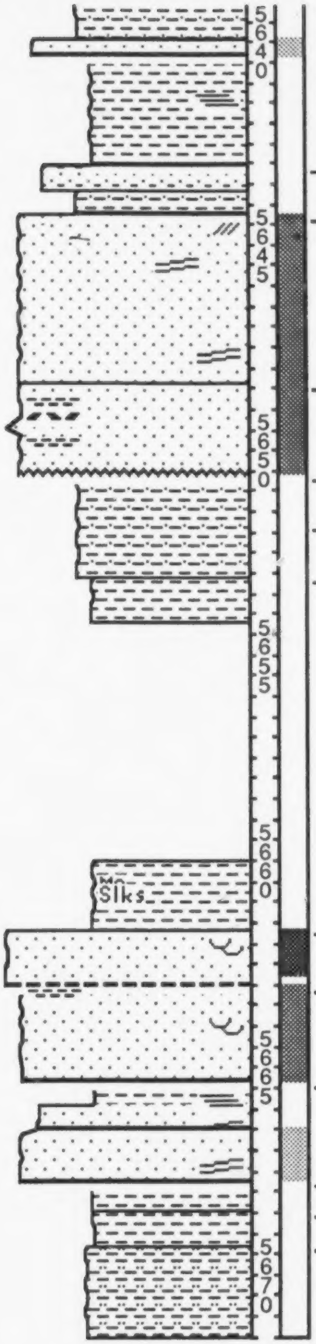
gry anhy sh

dsky grn - (gry-blk), hrd blky sh

pl ylsh brn fg ss, nearly completely cmtd, intb w/ dsky grn sh(incr intb down), ss is horz bdd and cur ripples throu (psbl combined flow rip), few distur areas w/ small mud clasts.

grysh grn hrd blky sh

horz lamd mixed drb-grysh grn sltst. dsky grn sndy sh, 8in of patchy cmtd fg ss



thin cg-peb mdy ss in upper 6 inch of this unit. rest is a fg-cg mdy ss

mg -fg ss, high > @ top, mass in mid and low > @ base, few scat mud clasts @ top.

mg-cg ss, w/ thin 5cm sh near top (sh fsl & mic), cg is very fsl & mdy

pl grn sndy sh, hrd blky

drb sndy sh., brec @ base

mixed drb pl grn sh, very mic, sndy ip. slks

cg ss peb ip in upper 40 cm,

mg ss trough ip and horz ip, thin 2cm mud capping this seq.

intb mg-fg ss with sh (lams-4cm) mainly low > bdng, bot 20cm mg-cg ss w/ low-high > xbdng.

pl grn hrd blky sh

drb hrd blky sh

mixed drb-plgrn sh, mostly drb, very irreg, sandy ip, horz bdd ip

Amoco Unit 213

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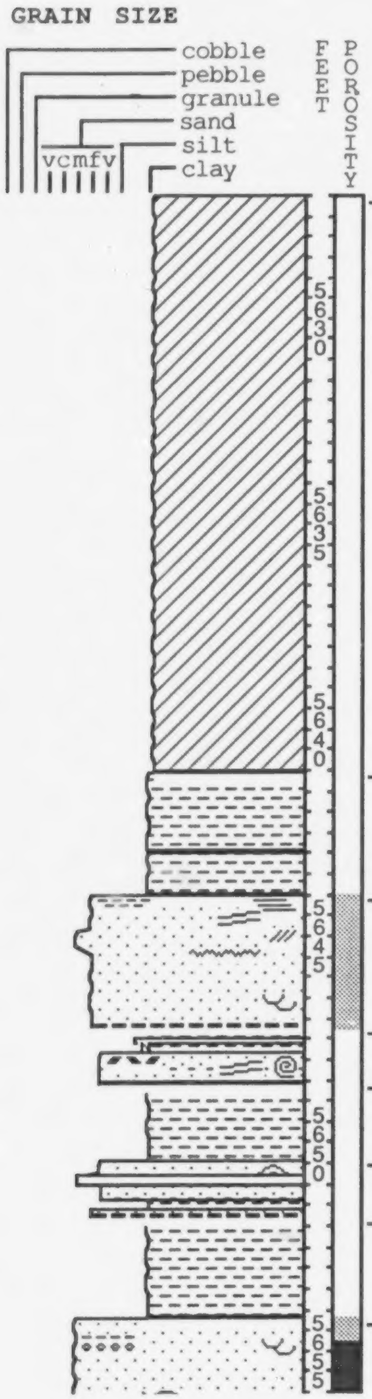


intb anhy sh & grysh grn sh

dsky grn hrd blky sh @ base up to more gry, upper10 cm is blk horz lamd

base up to minor scour, (fg ss well sorted trough through, incr in mud lams up,) upper fin up seq,(m-cg @ base w/ high angle bdng, up to low angle bdng and horz @ top , upper horz bdd has mud lams)

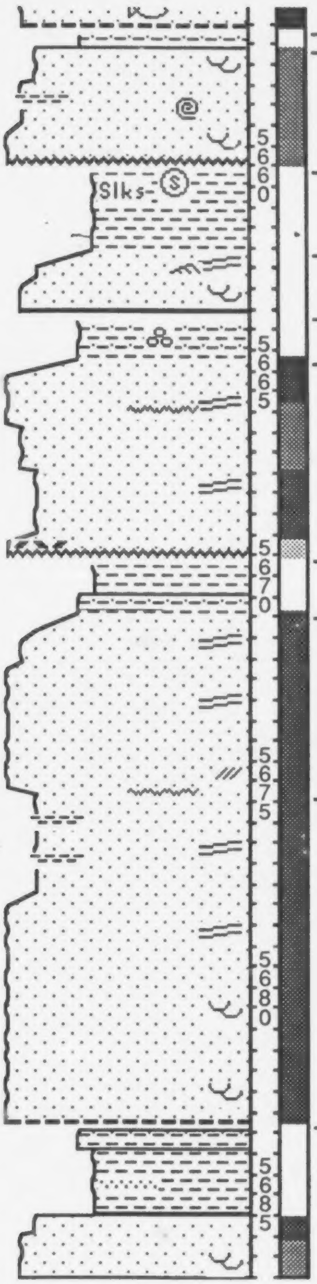
fin up seq, base fg ss w/ low > bdng enhanced by shly lams up to a intbd sndy horz lamd sh w/ dsky grn hrd blky sh

dsky grn mod blky sh

intb mg ss w/ cg-peb w/ fg horz lamd and psbl wave rip, dsky grn hrd blky sh

base dsky grn mod fsl sh, upper half dsky grn - gry hrd blky sh

m-fg ss, fin up, shlyr to top giving ol col, trough throu,1cm peb zone 12 cm from top



grysh grn sndy sh

cg-fg ss, fin up, cmtd crsr bds @ base, mid mg ss w/ mud rip up clasts and conv bdng, upper fg ss w/ trough xbdng

lower mixed grysh grn and dsky rd mod blky sh, upper17cm is grysh grn hrd blky sh w/ slks & microslks

m-fg ss, fin up, lower mg ss w/ cg cmtd zones, trough xbdng, upper fg ss w/ cur rip & horz bdng

grysh grn sndy sh w/ minor limy clasts

cg-fg ss, overall fin up gradational contact w/ sndy sh above. base cg lag w. mud rip up clasts, mid is fg w/ pulses of m-cg ss(low > bdng), mg ss (low > bdng) above minor scour grading into grysh grn sndy sh above

upper 10cm lower sndy sh &upper14cm is grysh grn hrd blky sh , mid 11cm is drb-dsky rd hrd blky sh, sharp contact betwn these units

fin up seq,cg-fg, lower cg ss high > bdng(few scat peb)- mid mg ss low > bdng, upper fg ss high > bdng

fin up seq, base cg trough xbdng w/ scat peb 1 (1.5x1.5cm), upper fg ss w/ low > xbdng, scat mud clats and lams

overall fin up seq, base ss mg trough xbdng, upper ss fg indt bdd, sharp horz contact w/ upper grysh grn hrd blky sh sndy ip

C. Norex et al NIPISI

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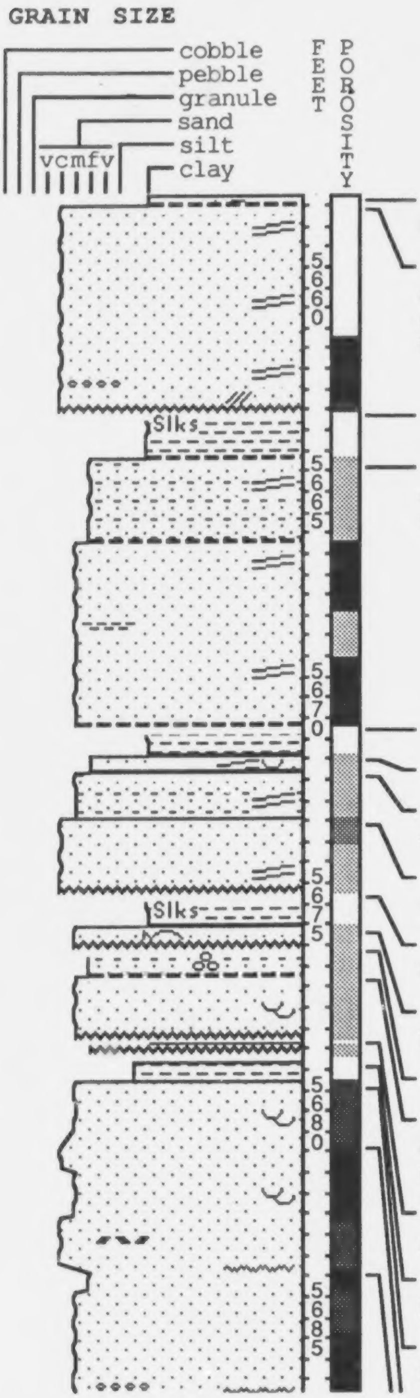


dsky grn - ol gry hrd fsl sh, one large 3x6cm fish plate found

pl ylsh brn cg ss, low > bdng throu, bot 1/3 of unit has cmtd patches, few scat pbl near bot of unit (2x1cm), core is crumbly to touch and better srtd than other crs gr units, 6cm fr top is a 3cm thick fg lamd bed

dsky grn hrd blky sh, slks

pl-dyb ss, fin up med-fg, bot 25 cm is cmtd and contains abnt peb, faint low > bdng throu, parts of mg ss contains abnt grysh grn mud lams. upper fg unit is shly

intb drb-grysh grn sh, hrd blky

fg lamd pl ol ss, w/ low > lams @ base and trough @ top

mixed drb-dsky grn shly snd, some sndy pts show low angle bdng

pl ol crs gr ss w/ scat peb, faint low > bndg, bot half of unit is cmtd

dsky grn hrd blky sh, slks, core is twisted from the core barrel

pl ol - pl ylsh brn mg ss, nearly completely cmtd up, 2 long 7cm bones.

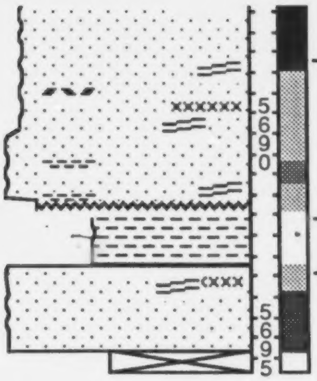
dyb fg shly ss, sparce limy blebs near top

pl ol- pl ylsh brn mg ss trough bdng , nearly completely cmtd up giving it a lighter color appear, becomng shly toward top.

intbd sh-mg ss, upper sh is grysh grn sft blky, ss is pl ylsh brn cmtd, lower sh is dsky rd hrd blky.

sndy sh lower half in contact w/ ss is grysh grn, upper half dsky rd,

mod-pl ylsh brn mg ss w/ abnt scat crs gr & peb. trough bdng.



fin up cg -mg dyb ss w/ few scat mud clasts and peb. faint trough bdng and upper 30cm of box is broken up cgss rubble

mainly mg ss w sparce cmtd zones showing low > bdng, gen bdng can not be seen giving mas appear, two peb horizons w/ peb 4x2cm (yes)

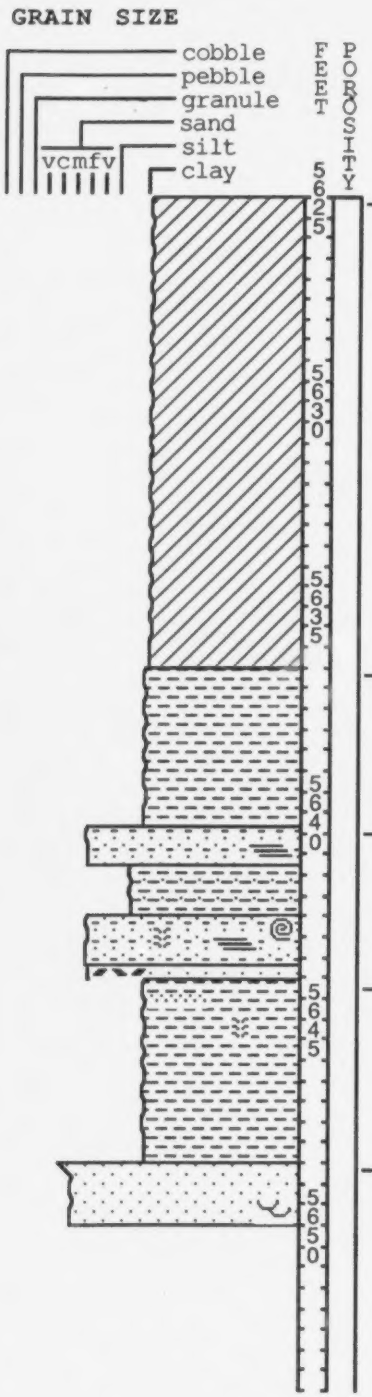
dyb ss fin up, crs-mg ss, mainly low > bdng, scat cmtd zones following bdng, scat small mud clasts 1x1cm, scat thin mud bds in lower part,.5-3cm

mixed drb-grysh grn hrd blky sh, very slty&sndy at base,

pl - dyb cg ss abnt cmtd patches and low > bdng through

Texaco Texcan Nipisi

10-35-78-8w5



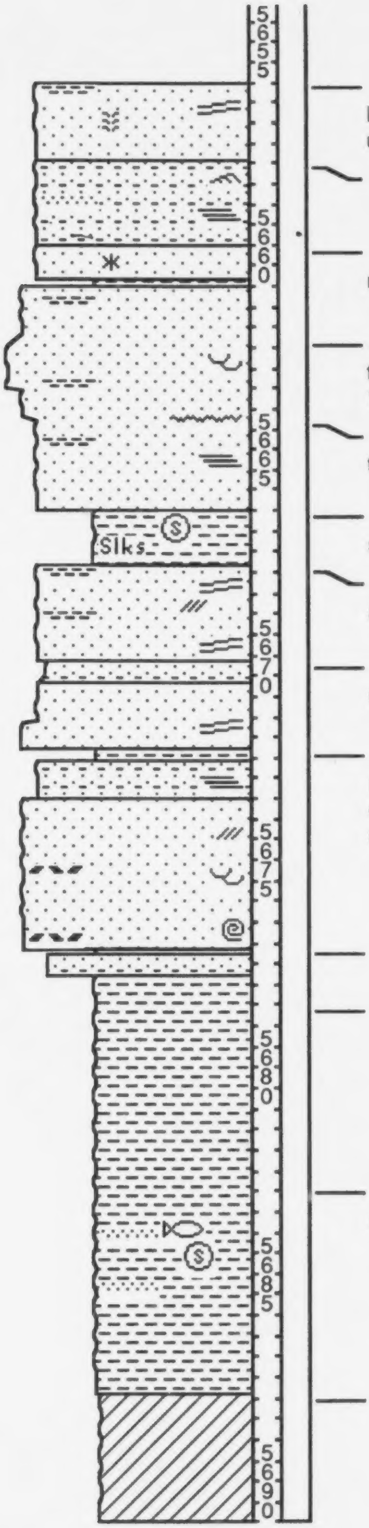
intb anhy sh w/ dsky grn hrd blky sh

dsky grn - gry hrd blky sh, fsl on edges ip

fg shly ss - intbd ss sh, basal 12cm is mas fg ss cmtd and contains mud clasts, lower shly ss unit has approx horz bdny but wavy and contains abnt water escape featuresl

dsky grn hrd blky sh, fsl ip & sndy ip w/ wtr escape features

mg ss w/ trough @ base and crsr cmtd bands, upper 7cm crsr gr
but minor scour underneath. cp 3-4



fg ss, low angle planar bdd @ base for 14cm, upper part low > planar xbdng, water escape in mid of unit and shly@ upper 5cm cp 6-8

fg shly ss horz lamd @ base & cur rip @ top,

fg ss, upper half mass,fair sorting ,lower half shly and mass cp 11-14

cg ss crumbly ip poorly sorted,trough throu(hard to see), thin 2cm grysh grn sh in centre of unit, ss quite shly ip cp 15-17

fg ss w/ abnt horz dsky grn sh lams, bdng approx horz throu, cp 18-20

drb med blky sh, slks & microslks throu, (all broken up), sh is pl grn for 2-3cm @ upper and lower contacts

fg ss w/ low -high > bdng, dsky grn sh lams throu (not always continuous) incr to top, cp 22-23

mg-fg ss fin up mainly low ? xbdng, capped by dsky grn sndy sh w/ low angle parallel bdng, ss cp 24-25

top of fin up unit, m-cg @ base w/ conv-trough xbdng ,to mid mg ss high > bdng,top horz lamd fg ss w/dsky grn sh, capped by 5cm dsky grn hrd blky sh ss is cp26-33&34 is in sndy sh below

grysh - pl grn hrd blky sh sndy ip

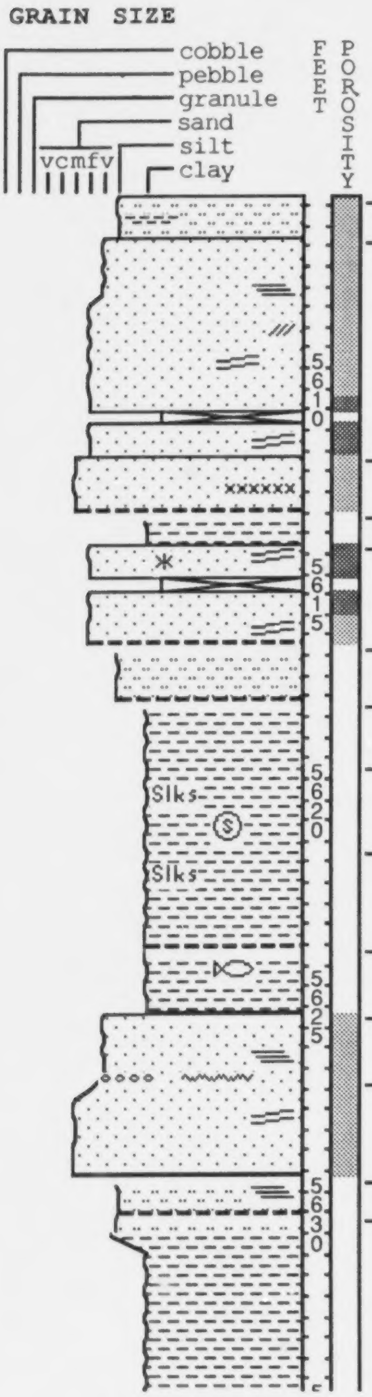
drb hrd blky sh

vgtd hrd blky sh, (dsky rd , yel, pl grn grysh grn, anhy ip, microslks ip

tan anhy sh intb w/ thin cm scale grn sh

Shell et al Nipisi

10-36-78-8w5



This core contained many boxes of rubble therefore a caution should be used when determining depths and thicknesses. pl grn vfg ss-sltst with abnt grsh grn sh lams disc and wavy. mg ss lag at top

pl ysh brn fg-vfg ss well sorted, sed struc incld planar horz, low >, high >, convd.

mg pl ysh brn ss nearly completely cmtd, two 1cm anhy clasts near top

grysh grn mod fis sh. 5cm mg ss at base cemtd up

pl ysh brn fg ss excellent sorting, mainly low angle lams, mass ip

grsh grn mas sltst, sndy ip

dsky rd sh broken up rubble hd blky

dsky rd sh hrd blky, brec appear ip, slks and micro slks

dsky rd sh grsh grn ip sft fis, abnt slks and micro slks, grn sh is wxy.

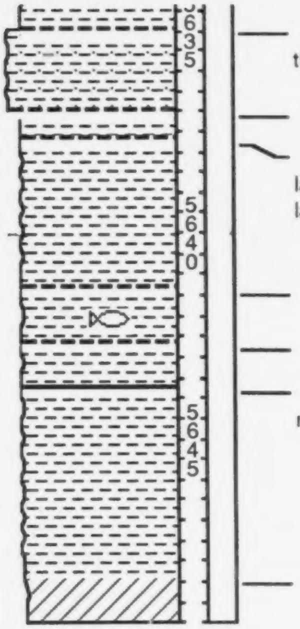
very broken up, dsky grn sh,

mainly vfg ss with fg-mg beds and scat crs gr ip. muddy ip shown by blk lams cont and disc

mg ss with some fg beds and crs gr beds and scat grains, overall fin up mainly planar xbeds, most is cemented

grsh grn sltst w/ disc approx horz lams

drb hd blky sh, broken into sm blky pieces through except upper 15cm which is more silty



grysh grn sndy sh, ss is fg and is both scat and found in thin 1cm bds

blk sh w/ dusky grn patches, bracks

vgtd, tan ,grysh grn, dsky rd, generally horz lams-massive. top 20 cm is very variable in color w/ horz lams and frac

dsky grn blk ip hd fis sh, fish plate found in dsky grn sh

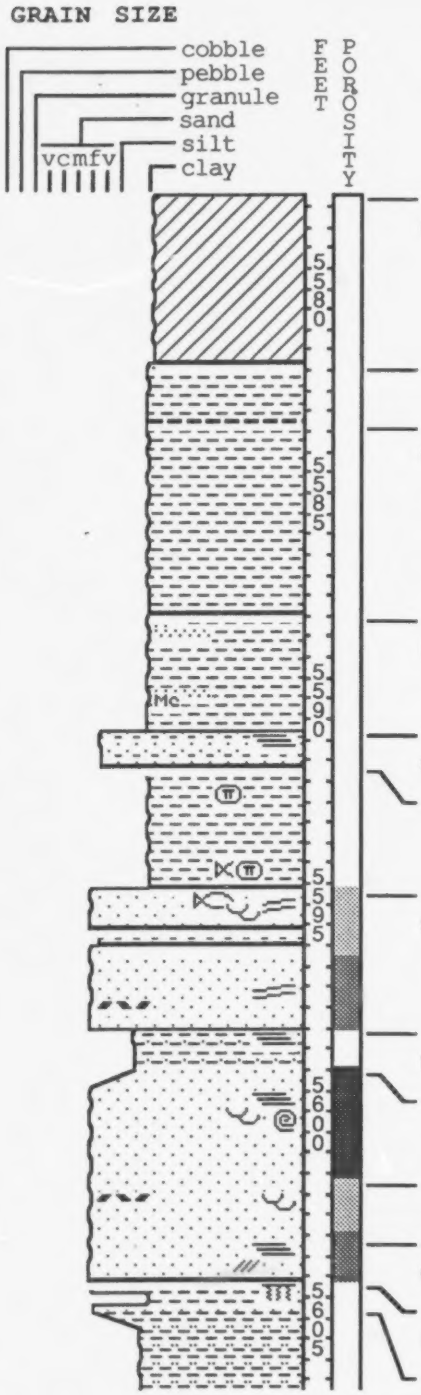
mottles drb pl grn and dsky rd, yellow ip

tan sh anhy? mas w/ few planar and wispy blk lams, nodular appear 25cm from top

gry anhy horz lamd conv at top w/ upper unit

Amoco Unit 353 Nipisi

4-18-79-7w5



intb white horz lamd anhy w/ drk brn horz lamd anhy, all calc

drk brn horz lamd anhy sh

dsky grn - gry very hrd blky sh, bot contact has 3cm blk fsl sh

dsky grn - gry mod blky sh, very mic throu, vfg sndy bds (1-3cm thick horz lamd) ip

vfg shly ss, perfictly horz lamd, very mic on broken surfaces

dsky grn - gry hrd blky sh, fsl ip, scat minor fish scales

mg ss trough @ base low > to top, fish plate 3cm from top of unit

fg shly ss-sndy sh, dsky grn, climbing rip @ base - horz to top

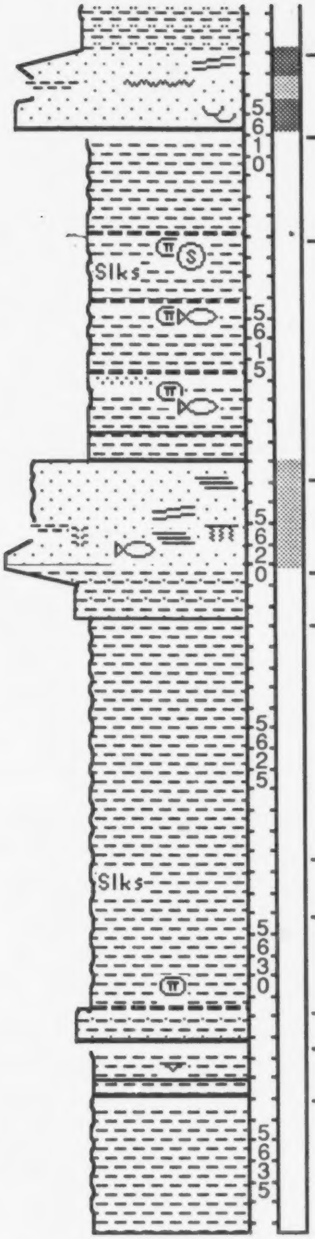
fg ss, chaotic bdng @ base, pos troug, upper planar lamd

mg ss trough bdng, less muddier than below

cg mdy ss , w/ few mud rip up clasts @ base, high > bdng @ base to almost horz at top

intb fg ss w/ grysh grn sh, bds .25-1cm thick, fish plates & psbl bur

grysh grn mass very sndy sh, sndyness decr up



mg ss w/cg lag, fin up to minor scour then fin up again, crsr bands cmtd,top of lower snd is10cm grysh grn sndy sh

upper drb hrd blky sh

intbd grysh grn waxy sh w/ microslks mixed w/ drb brec in appear. grn contains fish scales and plates, drb mainly hrd blky w/ some brec and microslks; lower drb hrd blky sh w/ abnt mixed grysh grn and microslks ip, fish plates and scales

fg ss w/ m-cg lag, lower horz lamd w/grysh grn sh syn cracks, mid low angle bdng, upper horz lamd w/ grysh grn sh, large fish plate 7cm long @ base

grysh grn sandy sh, psbl horz bdng when sandy, snd mg-fg

drb-dsky rd hrd blky sh, sandy and horz lamd ip,

vgtd drb-pl grn sh, slks and mud cracks, many mud cracks are infilled w/ sand, sh is waxy ip and sandy hard blky ip, pl grn follows fractures

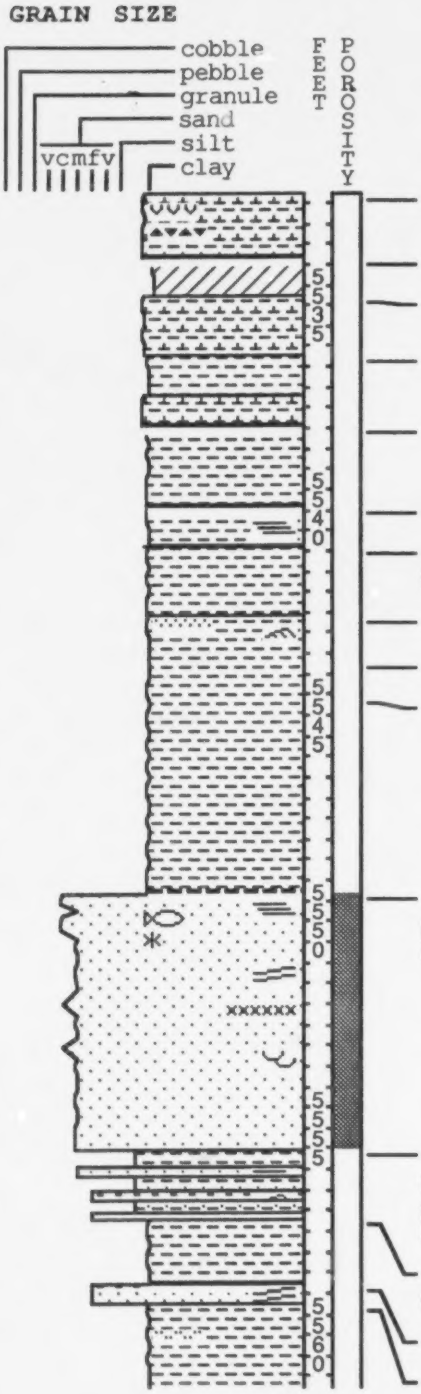
15cm pl grn hrd blky sh

grysh grn slty-sndy sh, dist-horz bdng, upper contact is sharp w/ 5cm pl grn waxy sh,

grysh grn slty-sndy sh, dist-horz bdng, upper contact is sharp w 5cm pl grn waxy sh w/ slks

tan vgtd anhy sh

HB BA Nipisi
12-20-79-7w5



calc sh w/ anhy, breciated ip, dyb @ base tan @ top

solid anhy

calc sh horz lamd, dyb-ol gry

ol gry hrd blky sh @ top and blk very fsl @ base

ol gry hrd very fsl sh

dyb-tan anhy sh hrd blky horz lamd

grysh grn sh, general discription for whole unit, v fsl ip, hrd blky ip

grysh grn sndy sh, starved rip,

grysh grn soft fis sh just below the sndy sh

med - hrd fis sh

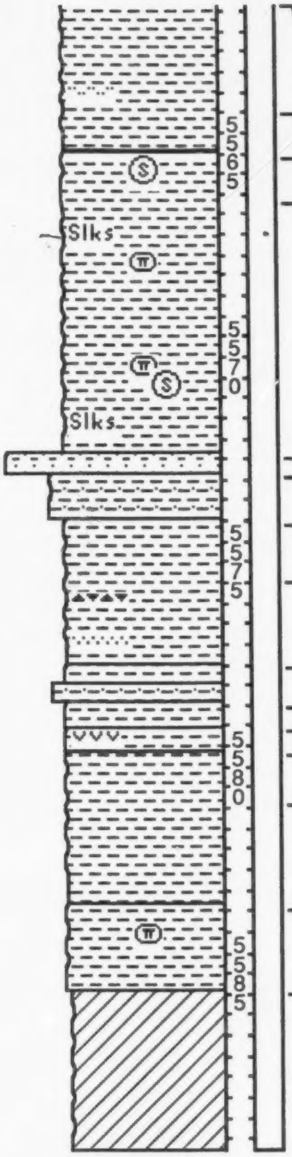
dyb um-lcg ss, trough @ base, low angle in mid, and planar bdng @ top,
mass ip, fair porosity throu, few smtd patches of crsr gr ss

intbd grysh grn sndy sh 4-10cm w/ pyb shly ss 2-5cm ss has
planar bdng & starved climbing ripples, mostly fg, upper ss is mg

upper half mixed drb&grysh grn mod fsl sh, lower half mod fsl grysh grn

grysh grn shly snd, wavy low angle bdng,

upper 1/3 of unit is mixed drb & grysh grn soft fsl sh



mudy ip-, med 1/3 of unit is a ol gry slty sh mas-, bot 1/3 is grysh grn med fis sh,

drb - dsky rd sh , hrd blky at base & slty, bcmg more fsl up to top, upper 25cm is ol gry mod fsl sh.

drb very fsl sh, same type of sh as grysh grn below,

grysh grn very fsl sh,

very broken up mod soft fsl sh, mixed color throu dsky red-drb w/ grysh grn, v fsl throu, fish scales, few slks and microslks

pl ol fg shly ss, gen mass, horz bdd ip.

grysh grn sndy sh,, horz sometimes discontinuous bdng, very fsl

drb med fsl sh

breciated drb-dsky rd sh w/ grysh grn sh, few thin 1cm ss beds

upper unit grysh grn very fsl sh,
lower unit grysh grn sndy sh, sharp contact betwn,snd gr f-peb

vgtd sh as below

tan anhy sh horz lams

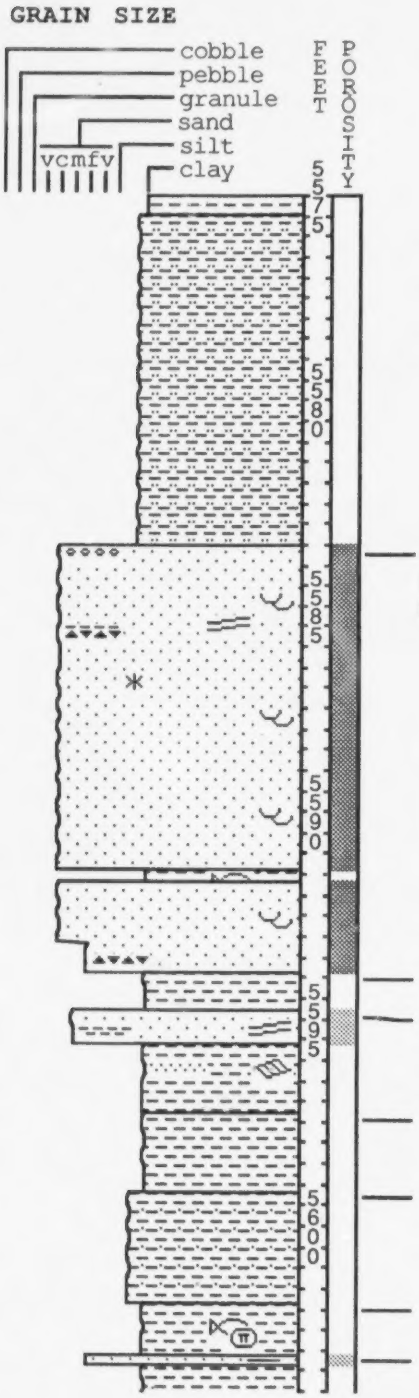
intbd blk fsl sh w/ dyb mudstone (looks like boudinage struc)

vgtd drb, tan grysh grn, reddish, med slightly fsl sh

mixed ol gry-blk sh, mod fsl

tan anhy

FPC Nipisi
12-30-79-7w5



dyb cg ss w/ scat pbl and fg sd. fairly well srtd, upper 5cm is a pbl layer, few scat md clasts, fish plate in the thin sh bed

grysh grn sh mod fsl.

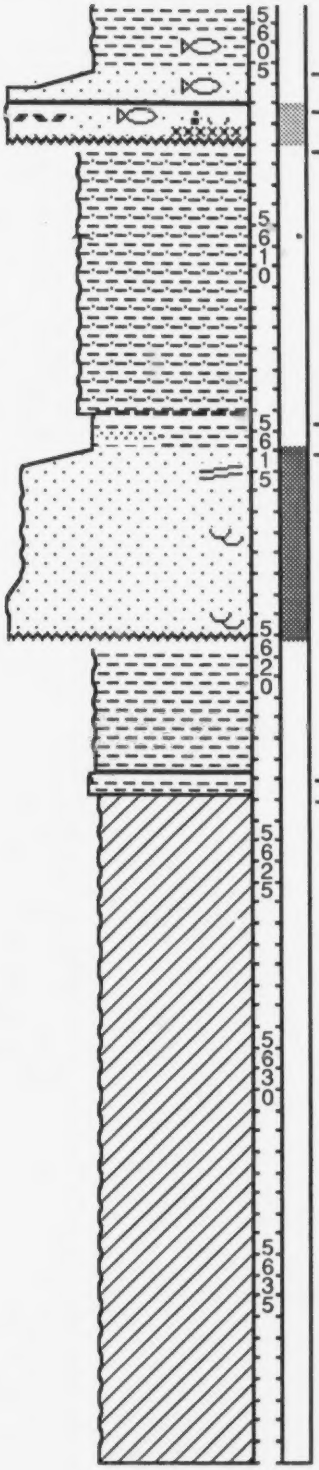
pyb md ss w/ cg lag, thin mud bds 3mm, low ang bdng.

dsky grn-gry hrd fsl sh

dyb sndy sh hrd blky

grysh grn sft fsl sh, mixed w/ drb ip, fish scales throu,

pyb-pl ol horz thin bdd fg ss



intb fg ss (1-2cm) w/pl grn sh hrd blky bot half, top half w/gry-blk hrd fis sh. fish plates & pos bone.

pyb ss cg-fg fin up, mud clasts, fish

sndy sh bot 19cm (irreg mixture of grysh grn&dyb), mainly dyb sndy hrd blky sh, upper 22cm is pl ol.

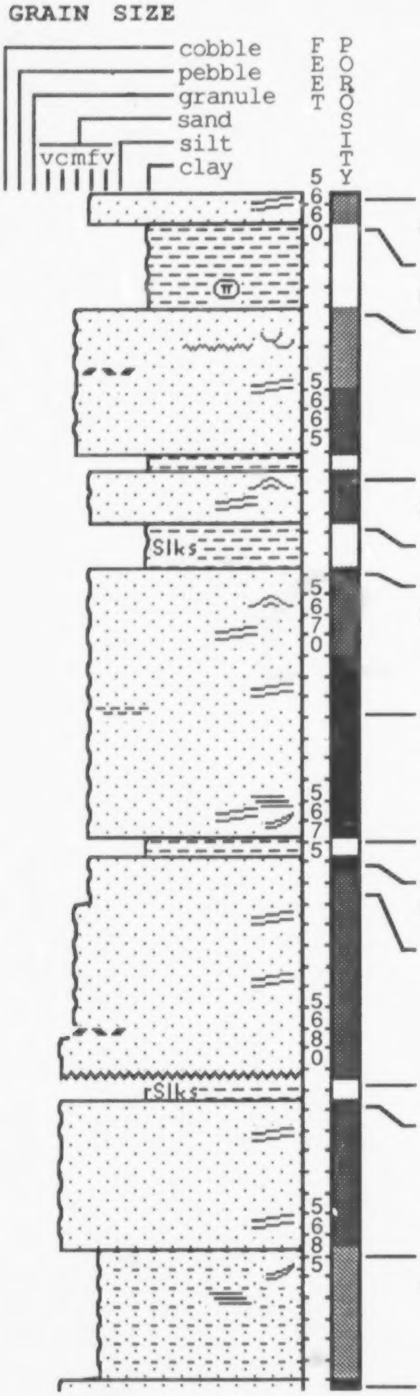
pl ol slty sh, sndy toward base.

pyb mainly mg ss w/ trough and planar bdng

tan-blk calc sh

Top Muskeg

Amoco Unit 216
2-3-79-8w5



fg ss low angle bdng @ top, well sorted and bdng hard to disc @ bot

dsky grn - gry @ base hrd blky sh, fsl on edge of core pieces, abnt fish scales at base of unit

mg ss w/ sm & lrg mud clasts, low angle bdng throu

fg ss mg @ base, low > bdng- pos wave rip@ top. a 3x1cm anhy clast 2cm from top of unit

mixed drb-grysh grn sh, scat sand grns , slks

fg ss w/ flaser bdng @ base, low > bdng throu- pos wave rip near top

1cm very mic shale bed.

very mic dsky grn sh 13cm thick

mg ss low > bdng throu, large 6x2cm anhy clasts w/in a 8cm zone near center of this mg ss

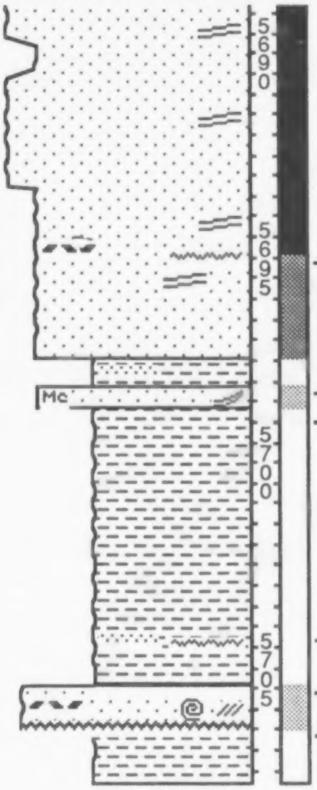
anhy clasts 2x6cm

dsky grn hrd waxy sh, slks

cg ss, bdng hard to see. looks like low > bdng

ol fg shly ss, flaser bdng. disc horz mud lams, scat m-cg sand through

peb-vcg ss, fin up, bdng very hard to make out, pshl low >



throu, well srtd for gr size, psbl wave rip. some subrounded grns

fg ss, uf-med at base, low angle bdng through,ss grns are somewhat rounded, and pos wave rip near top. sorting is excellent in places and makes bdng hard to see

fg ss indet bdng pos wave-cur rip

drb hrd blky sh, upper 10cm is pl grn

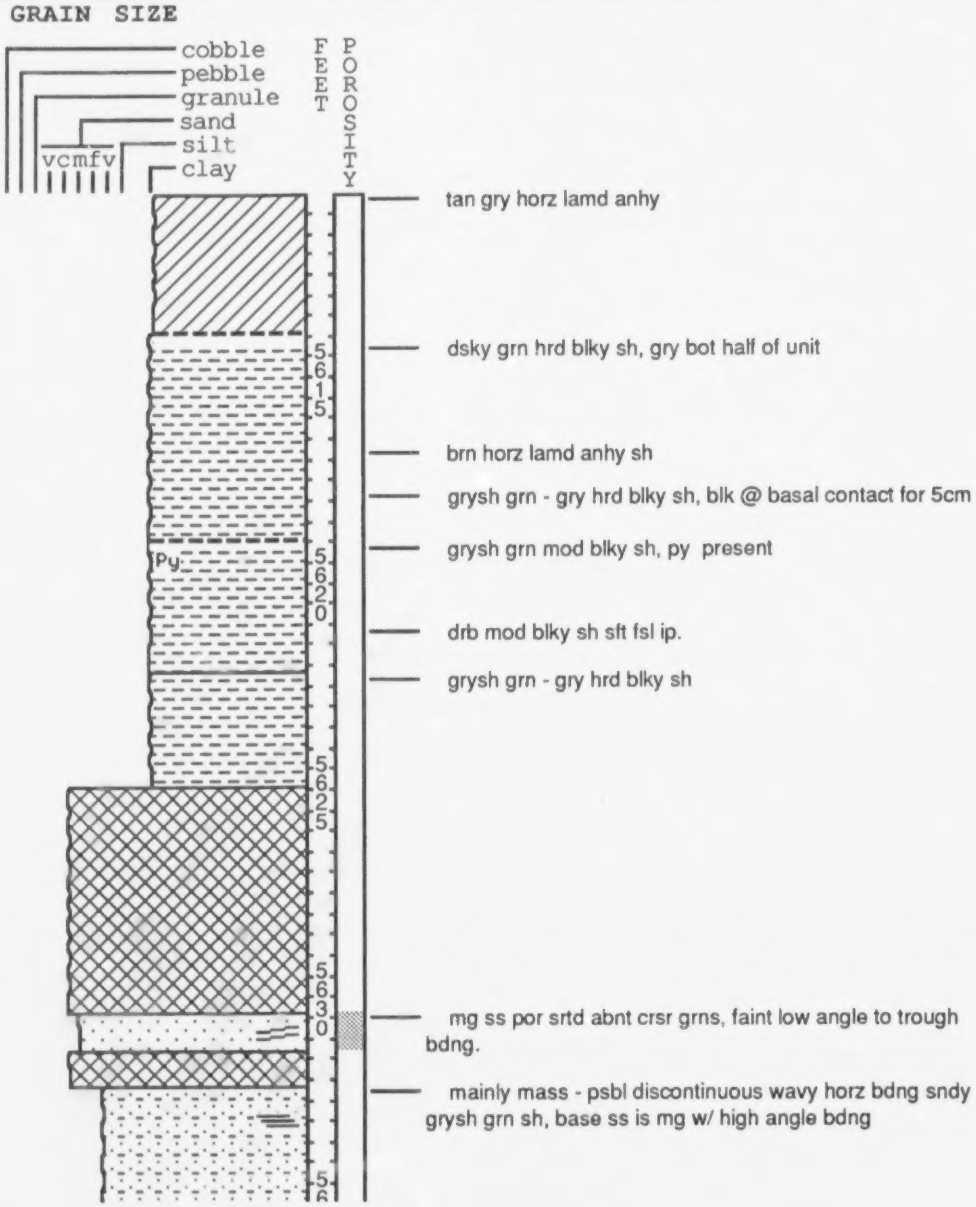
4cm f-mg ss w/ scoured base.
15cm of pl grn waxy sh underneath ss, & mixed drb-pl grn down to next ss.

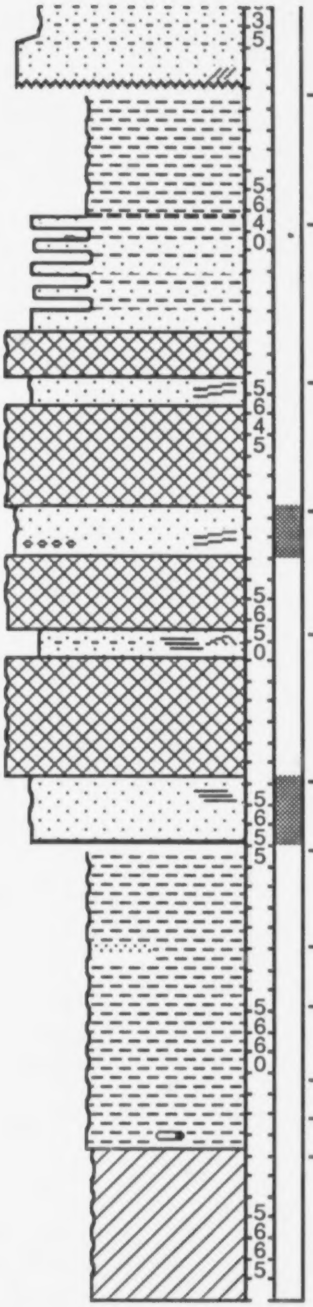
mg ss completely cmtd, high > bdng - churned, one large mud clast, almost a bed in centre of unit. upper contact is w/ 5cm pl grn sh

mixed pl grn-dsky rd sh, upper 13 cm is pl grn only

Amoco Unit 310
12-12-79-8w5 SS Covered by Wax

Remarks: Almost all ss is covered by orange wax to
preserve original reservoir characteristics


GRAIN SIZE
cobble
pebble
granule
sand
silt
clay
vcmfv
FEET
POROSITY
tan gry horz lamd anhy
5615
dsky grn hrd blky sh, gry bot half of unit
brn horz lamd anhy sh
grysh grn - gry hrd blky sh, blk @ basal contact for 5cm
Py
5620
grysh grn mod blky sh, py present
drb mod blky sh sft fsl ip.
grysh grn - gry hrd blky sh
5625
5630
mg ss por srtd abnt crsr grns, faint low angle to trough bdng.
mainly mass - psbl discontinuous wavy horz bdng sndy grysh grn sh, base ss is mg w/ high angle bdng
56



drb hrd blky sh upper 25 cm is grysh grn , upper parts of drb sh is grysh

intb sndy sh, sh and fg ss, grysh grn in sndyr parts and all contacts w/ sand and mixed drb grysh grn in shlyr parts

mg ss poor sorting, faint low angle bdng

mg ss fair sorting few pbl @ base, faint low > bdng

fg shly ss horz bdd @ base - climb rip @ top, very mic

fg ss-sltst, horz bdd, very well sorted

drb hrd blky sh, brec ip, upper 10cm is pl grn hrd blky sh.

mixed drb-grysh grn sh brec ip, sndy ip

grysh grn hrd slty sh

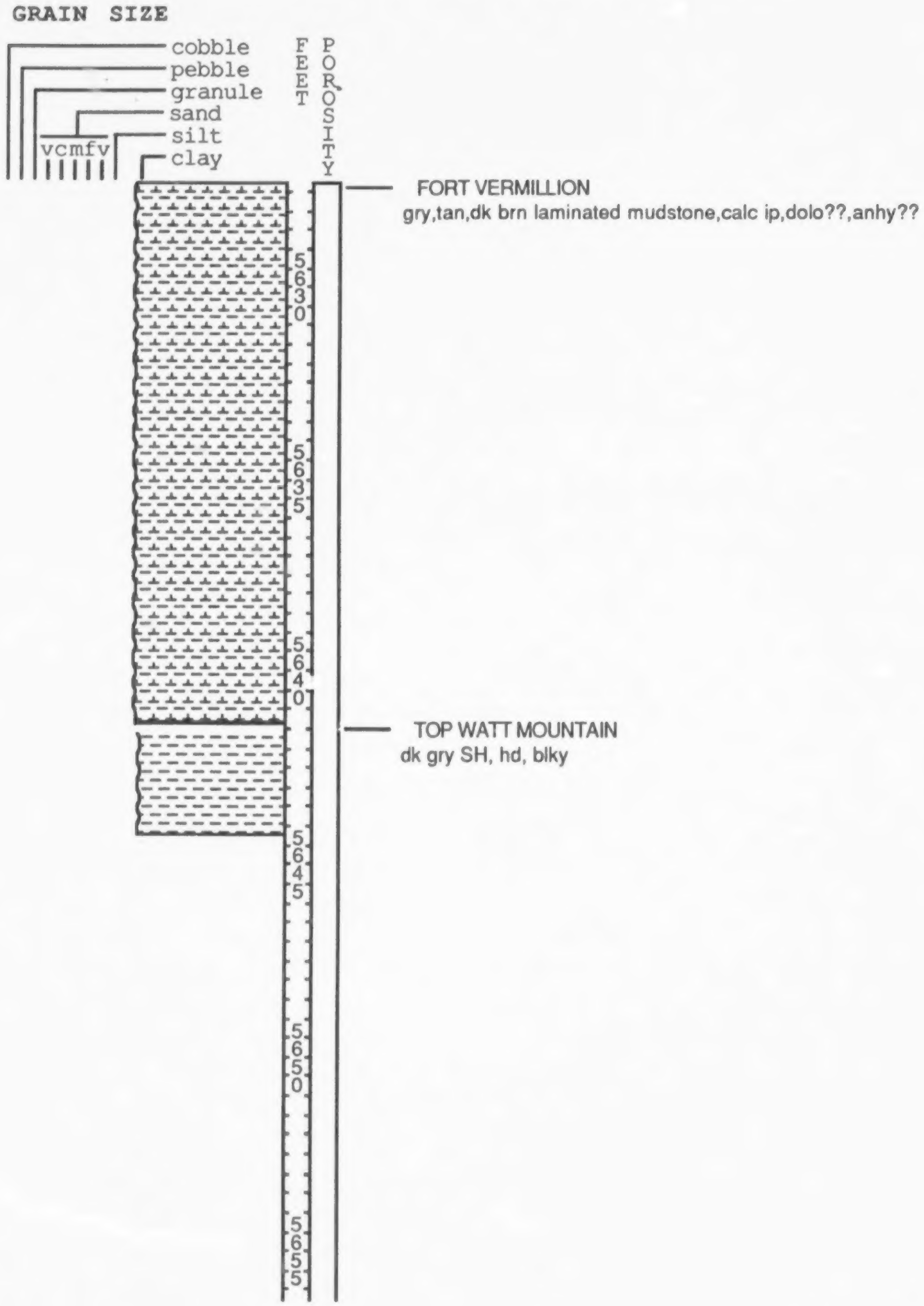
mixed dsky rd grysh grn mod blky sh.

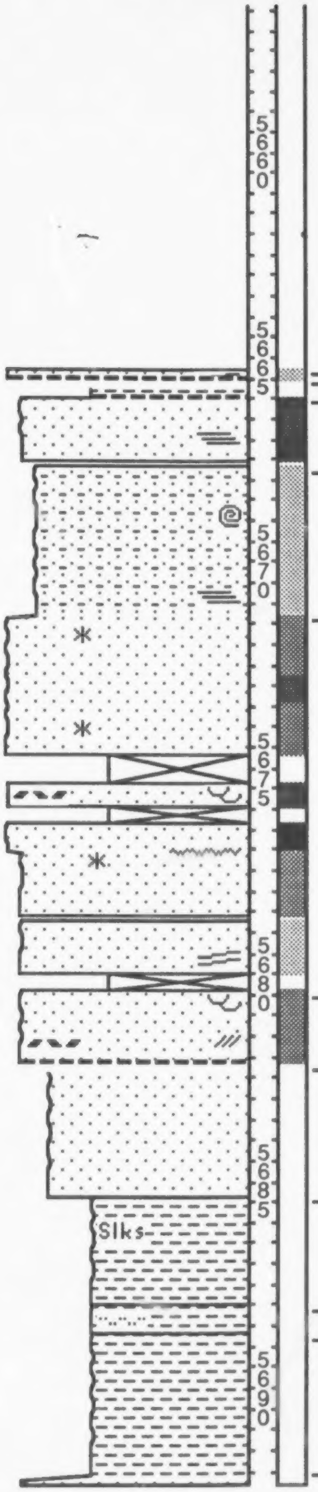
grysh grn mod fsl sh, very waxy, sndy @ base with plan or condrites

tan anhy sh, vgtd ip (yel, grysh grn, dsky rd) horz bdd

Shell et al Nipisi

4-14-79-8w5





pl ylsh brn cg SS, porly srtd

grysh grn SH, hd, sl fsl, scat f-crs grns

pl ylsh brn mg SS, flaser bdg, friable ss ip

pl grn mdy fg SS,grds frm below,bioturb ip,scat mg thru,hzntl md lam

pl ylsh brn crs-mg SS, mainly mass, wl srtd, rounded grns, ss friable ip

dk ylsh brn mg SS, abndt crs bds

top grysh grn SLTST,mass,bcmg shlyr; cntr grysh rd, bot pl ol SLTST, thnly lam thru w/climing rip&hzntl-wavy bds(5cm)

drb SH, hd, blky, occ slicks, grysh grn @ top 5cm

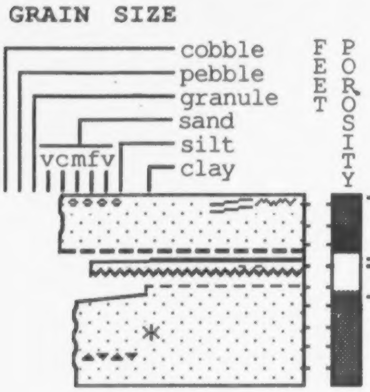
grysh grn SH, mod hd, fsl, slty ip

drb SH, hd, blky, occ slicks

pl ol mg SS, mdy ip, tight, v poorly srtd

Amoco Unit 285 Nipisi

10-14-79-8w5



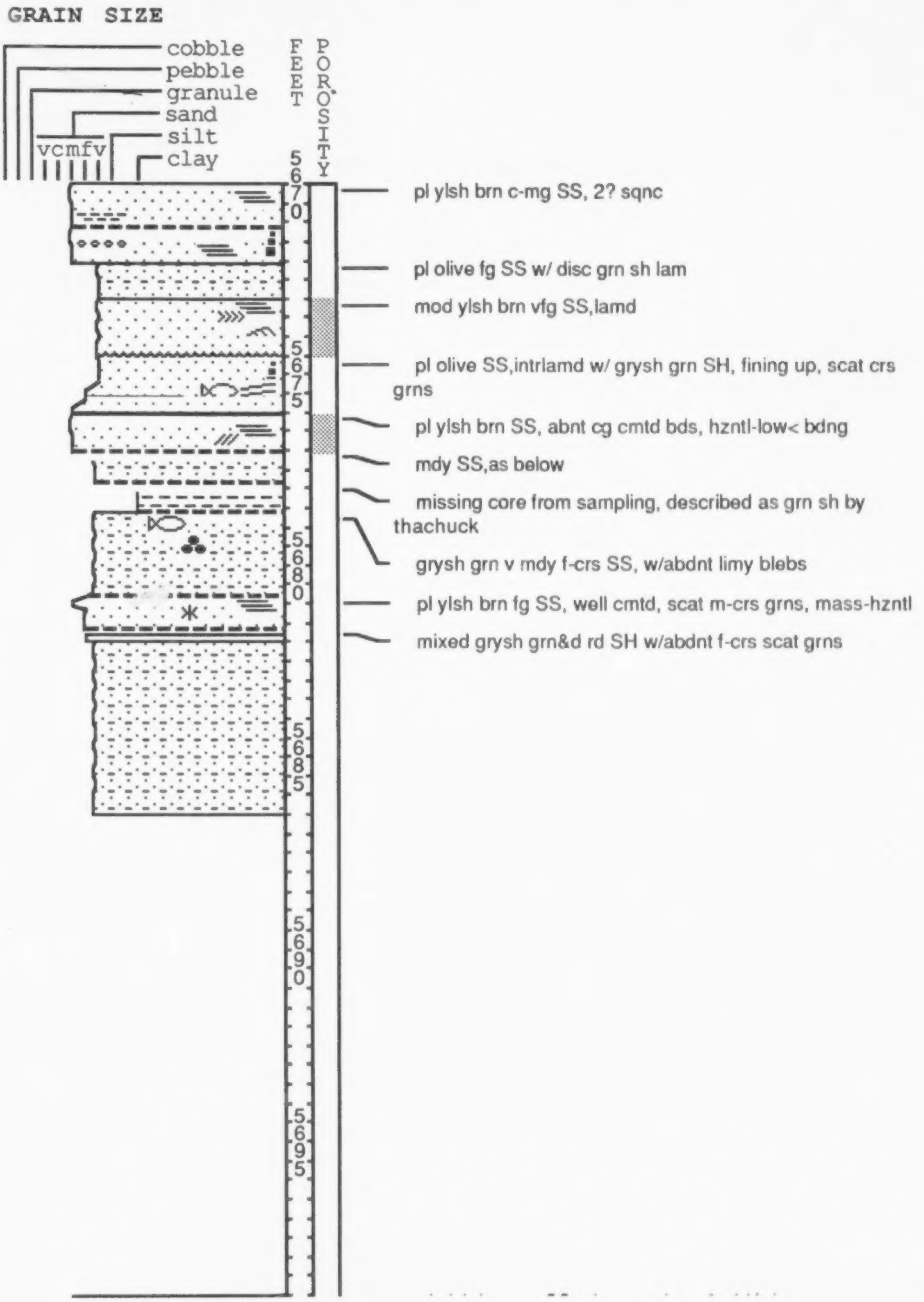
drk ysh brn crs g ss w/ faint low> - horz bdng, abnt scat peb at base, peb lag in upper 3cm of core

grysh grn sh soft fis , as sh below,

pl ysh brn fg ss w/ 1cm mg lag, 3 thin 1/2 cm cont mud lams,1 fish bone

mg pl ysh brn ss, crumbly to touch, mas - fnt low > bdng throu

Shell et al Nipisi
6-20-79-8w5 depths may be out



pl ylsh brn c-mg SS, 2? sqnc

pl olive fg SS w/ disc grn sh lam

mod ylsh brn vfg SS,lamd

pl olive SS,intrlamd w/ grysh grn SH, fining up, scat crs grns

pl ylsh brn SS, abnt cg cmtd bds, hzntl-low< bdng

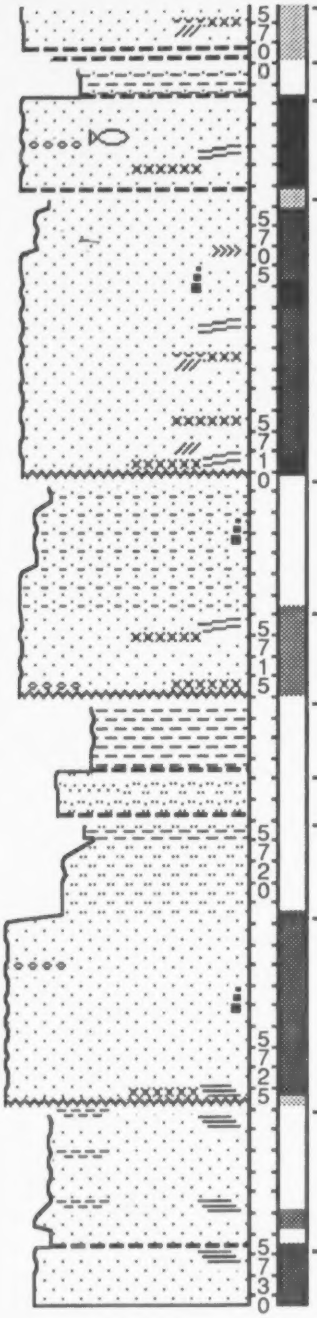
mdy SS,as below

missing core from sampling, described as grn sh by thachuck

grysh grn v mdy f-crs SS, w/abdnt limy blebs

pl ylsh brn fg SS, well cmtd, scat m-crs grns, mass-hzntl

mixed grysh grn&d rd SH w/abdnt f-crs scat grns



pl ylsh brn mg SS, abnt cmtd crs & pbl bds

mixed grysh grn & dsky rd SH w/ abdnt f-crs scat grns

pl ylsh brn mg SS,mnr crs&pbl cmtd bnds

pl ylsh brn mg SS, mnr crs & pbl cmtd bnds, bcmg shly @ top

mixed drb & d grn shly m-vfg SS, 5cm crs & pbl layer top

pl ylsh brn mg SS,abdnt crs cmtd bnds thru,low <

drb SH, scat f-crs grn thru, 15cm dsky grn vert fract, 5cm dk grn sh @ top

SLTST w/ grn mud lam & drb mg SS lenses

dsky grn & drb SLTST, abnt scat f-crs grns thru, bcmg shly @ top

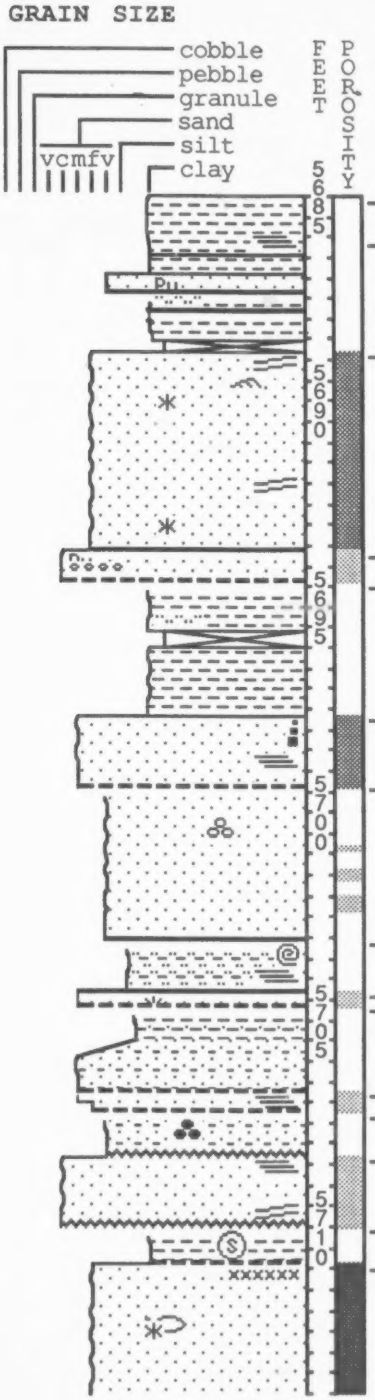
pl ylsh brn cg SS, fining up,bcmg mdy @ top, scat pbls up to 2cm

dsky rd, grysh grn, pl ylsh brn thnly lam fg SS, hzntl bdng, scat thin sh bds

pl ylsh brn fg SS w/ grysh grn md lam @ top

Shell et al Nipisi

2-21-79-8w5 Thachuk's TYPE LOG



grysh grn SH,hd,blky,mass,bcmg intbd w/ SS below

pl ylsh brn fg SS intlam w/dsky grn SH as above & below, bcmg more sndy and bedded toward base.

dk ylsh brn fg SS,few mg bds,fnt low< bdg,psbl ripples

pl ylsh brn SS w/abdt grn clst(2x1cm)&lam

grysh grn SH,hd,blky,few discont slt lam @ mid,sl fsl near btm

pl ylsh brn crs-fg SS,3 fining up sequence,thin grn md lam,scat pbls

pl olive vfg SS,thn hzntl-low<md lam @ base,lg limy sltst blebs incr to top giving mott app,scat pr por ip

grysh grn SLTST,w/ thn md lam,hzntl/wavy-churned

pl ylsh brn mg SS,abdnt pbls,mass

grysh grn mdy SS,abdnt calc cmt blebs-giving mott app,shlyr to top

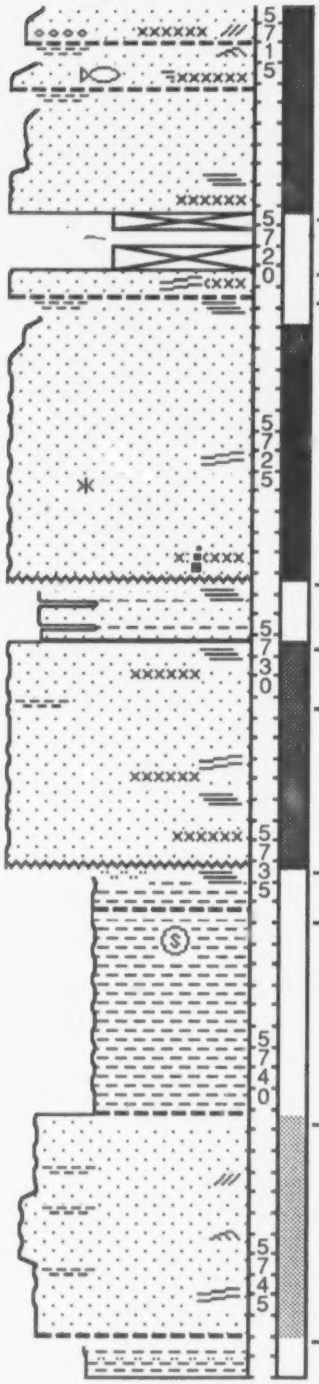
pl ylsh brn fg SS,abdnt scat m-crs grns

grysh grn fg-vfg SS,bcmg shly twds top,top 8cm abnt calc clasts

pl ylsh brn cg SS,low< x-bd,bcmg hzntl twds top

grysh grn&d rd SH,hd,blky,few micro-slicks

pl ylsh brn crs-fg SS,3 main fining up sqncs,scat crs grns thru, abdt @ top, red mdy lam@top of lwr sqnc, grn&blk md clasts @ top



lost core psbly d grn SH,v sft,v fsl

pl ylsh brn crs SS,cmtd,low < x-bdg

pl ylsh brn crs-fg SS,mass&low < bdg,crs cmtd bnds thru,mdy lam @ top, fining up

pl ylsh brn fg SS w/thn hzntl grn md lam,not calc

dk ylsh brn cg SS,v pr srt,abdt pbls(up to 1cm)thru,few thn mg bds, hzntl-low<bdg,cmtd bnds

5mm mud lam w/ pbls

grysh grn SH,hd,blky,scat slt lams

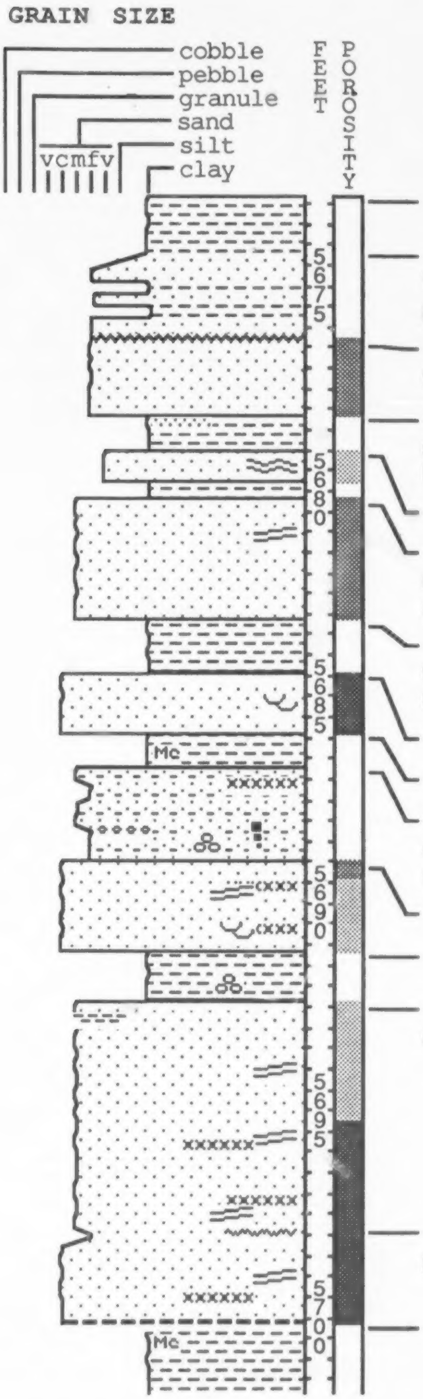
drb SH,fsl bcmg blky &mass @ top,few scat micro-slicks, scat pl grn shly ss bds, 6" msng core @ base assumed to be sh

grysh grn - drb mdst, scat crs grns thru top, sm curr rip & low< planar bdg

grysh grn & dsky rd slty SH, hd, blky

Amoco Unit 152

10-21-79-8w5



dsky grn hard blky slty sh

intbd vfg-slty ss w/ dsky grn-ol gry sh, ss bds approx 7cm thick & have horz to wavy bdng, sh is hrd blky, some possible burrows.

f-mg mod ylsh brn ss, mainly mas and well sorted, few mud clasts @top, faint trough xbds at base

intbd dsky grn - ol gry sh with fg lamd ss, sh is hrd blky & slightly mic,ss is drk ylsh brn w/ low> wavy disc bdng, peb lag at base.

fg interbed horz-wvy bedding w/ a peb lag

pl ylsh brn mg ss w/ indeterm bdng @ base & mud clasts up to 2x1cm, upper part is low angle bdng with pos plant (wood) frag 5cm long.

dsky grn - grsh grn hrd blky @ base mod & very fis at top,unidentified fossil at top, looks like a shell with lots of holes in it.

cg ss w/ abnt pbls, few minor cmtd bands

grsh grn hrd blky sh highly mic

grsh grn shly ss, apparent grading crs up, thin .5cm-2cm crs gr-peb bands not complete beds,few limy blebs @ bot, upper 14cm highly cmtd.

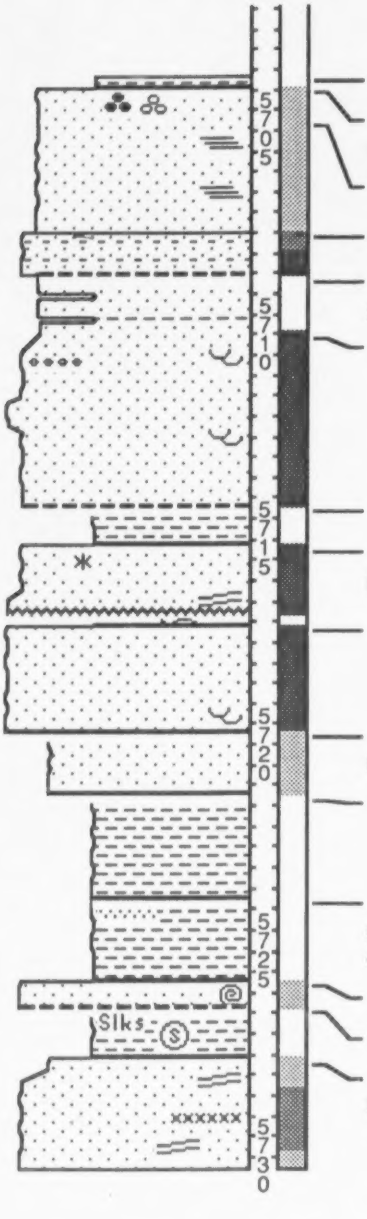
pyb mg ss w/ abnt cmtd crsr bands

mixed drb-grsh grn hrd blky sh w/ scat limy blebs.

Mainly mg ss with scat minor cemtd bands, some grsh grn sh lams in upper 27 cm

The 10cm below the minor scour is 4cm grsh grn sh & vfg pyb well sort ss

pl grn hrd blky sh w/ scat sand grs and peb, mic ip



dsky grn hrd blky sh

abnt sm limy blebs bcmg more dense to top w/in pl grn vfg ss

pl ol vfg-slts, horz bdng, blk mdy disc lams near top.

pl grn shly mg ss w/ scat crs gr @ base, bdng indeterm

intbd - mixed fg-mg ss w/ drb & pl grn sh, scat crs gr and peb

pyb mg ss w/ trough bdng & scat anhy clasts 1x2cm,

grsh grn hrd blky sh, lower contact 45 deg >

pyb mg ss faint low > bdng @ base w/ crs gr & peb ,up part mas, well sort

cg ss w/ abnt peb, trough bdng

vfg pyb-grsh grn ss w/ stacked 1cm climbing rip beds & horz beds, few burrows.

drb sh, med fis @ base and hrd blky @ top

hrd blky sh, one large frac. centre 2cm fg ss then ,5cm grn sh then drb sh. thin 4cm mg-fg ss bed above frac, capped by a pl grn waxy sh

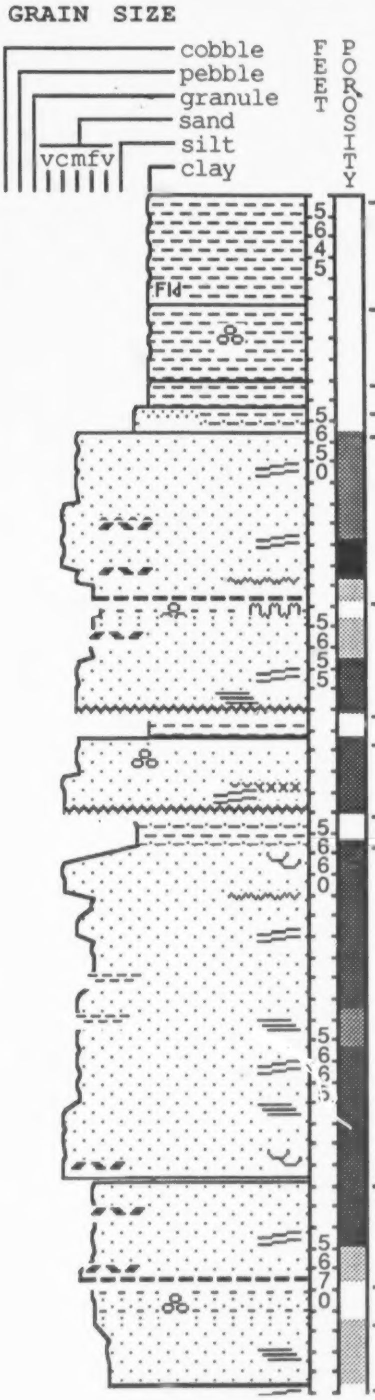
mg ss vgtd in colour mainly pale grn, pos faint low> bdng

mixd drb-grsh grn sh, abnt slks & microslks, hard fis

pl ylsh brn mg-fg ss, fin up scat minor cemt patches, faint low> bdng

Amoco Unit 286 Nipisi

2-23-79-8w5



dsky grn sh, sft fis, slty ip

grysh grn sh, hard blky, 3 limy clasts 1cm x 1/2 cm in center

dsky grn soft fis sh

dsky grn very sandy sh, sand grs are fg, capped by a 1cm mg ss bed

ysh brn mg ss, mod scat pebs. one peb bed w/ mud clasts w/in the crs gr ss. fnt low > bdng through.

grysh grn sndy sh grading from fg ss below, abnt limy blebs dense ip and surrounded by blk sty.

dsky grn hard fsl sh,scat f-med gr @ base

dk ylsh brn ss fining up, irreg calcite cmtd patches @ base & top

grysh grn sandy sh. abnt scat crs gr.

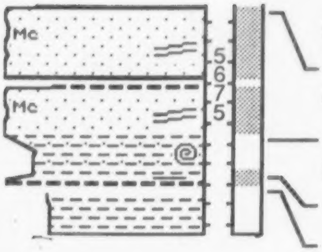
pl ylsh brn-dyb ss , 3 fining up seq

pl ylsh brn fg SS,low <,abdnt swel md clsts,1 kspar clst(5x10mm)

grysh grn pl ol drb mdy SS,bcmg mdyr & finer twds top, sm limy blebs

vf-fg SS, as below, sh lams

[illegible]



mxd grn & dsky rd sdy SH, abdnt sand grns thru, mt low < bdng

pl ylsh brn-drb vfg SS, thnly lamd w/mica, low< -hzntl lams

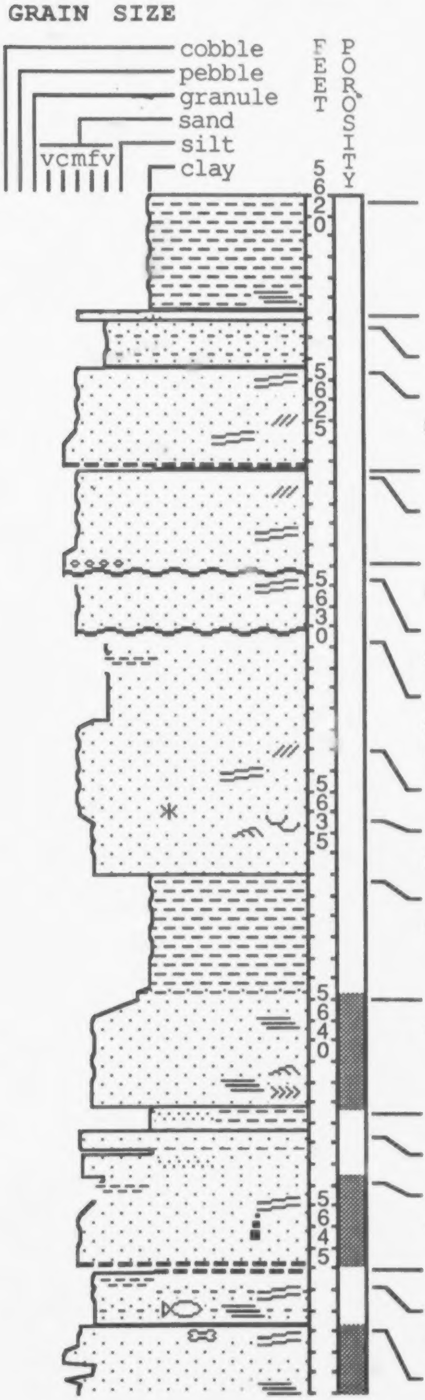
pl ol & grysh grn & drb sh, f-mg sdy SH, churned (slumped) @ base

pl ol vfg SS, thnly hzntl lam

drb SH, hd, blky, mass

Shell et al Nipisi

4-24-79-8w5



dk grn-gry SH, hd, blky sl fsl

pl ylsh brn mg ss w/ abt scat crs gr & pebls

pl grn shly fg ss, thnly lam, dewatering struc

pl ylsh brn m-cg ss, no apparent grading on lrg scale, stacked sm scale (1-3cm) fining up seqc

dsky grn sh, soft & blky - slightly fsl, abnt fg-med grs scat

pl ylsh brn med gr ss, scat cg's and pbl's.

bot 10 cm of pbl layer is churned w/ a grysh grn swelling clay

pl ylsh brn mg ss, mainly low > bdng, scat pl grn mud lams and pbl sized clasts.

vfg grysh grn ss, Some lams show low > bedng. contains scat crs grs and limy clasts which are surrounded by blk lams. Scat grs bcmg more abnt at base.

high > bdng in grysh ol fg ss (7cm) (slump feature)

only one 1cm set of current ripples, trough above and mas below

drb SH, grn sh @ top & btm10cm, mod hd,v fsl, scat micro fract thru

pl ylsh brn fg SS, thn pl grn md lams thru, grades into sh, scat crs grns thru upper part

grysh grn SH ,sft, fsl, abnt ss lam

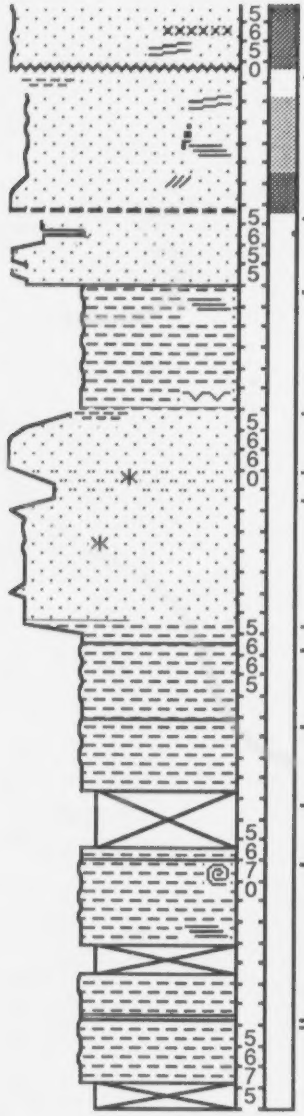
drb sdy SH intb w/ v sft, fsl sh

dk ylsh brn mg-fg SS, fining up, mg bnds, few swl cly clst & lams @ top

grysh grn SH, v sft, mod fsl

grysh grn fg SS, abnt mdy lam @ base decr to top w/1cm sh bd 10cm fr top

pl ylsh brn SS,variable grain size-no grdg,



pl grn fg SS, thnly lam w/ pl grn md @ top, hzntl bdg, scat med grns within 1cm along bdg planes;btm foot-dk ylsh brn mg-fg SS, high angle mg bdng thru

ntbd pl ylsh brn vf-mg SS w/ d grn MD & pl olive SLT

dk rdsh brn SH,fsl, micro-fract thru, dess cracks @ base

drb grd into pl grn mg SS,v pr srt,scat grns f-crs thru, mdy @ top

pl grn SLTST,hd,mass,scat f-m grns thru,top contact sharp colour change but gradational grain size change

pl grn fg SS,dsky rd @ top,svrl sqnces w/ mg 'lags', mass

pl grn SH, md hd, v fsl, scat grns

drb SH, mod hd, fsl, scat grns @ top

dsky grn SH, mod hd, v fsl, waxy ip, some dsky rd @ base

2.7' of missing core in last 10.3' of core

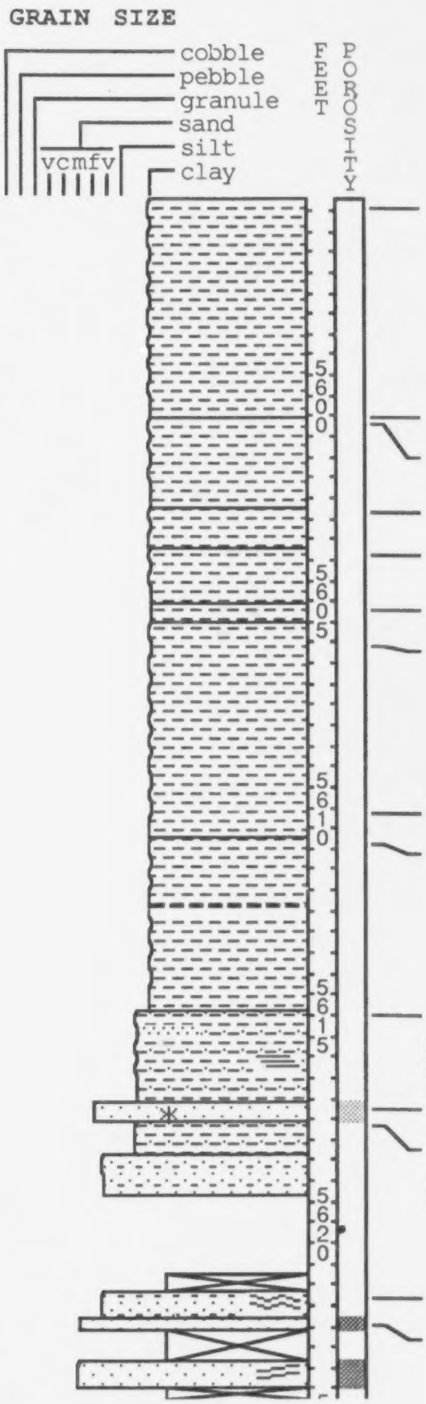
pl ylsh brn SH lamd w/ dk gry sh;some intrlamd grysh brn-pale ylsh brn-dk rdsh brn &grysh olive shales @top & base, hzntl-convoluted

blk SH, sft, v fsl, abnt scales, tr armour

pl ylsh brn anhy SH, psbl top Muskeg??

Shell et al Nipisi

12-25-79-8w5



intbd gry slightly calc shl w/ drk ysh brn lamd very calc sh

gry lamd sh

drk ysh brn lamd sh

gry lamd sh

grsh grn -gry hrd blky sh,

blk hrd fis sh py @ base,

dsky grn sh hrd blky ip fis ip,

mixed drb dsky grn hrd fis sh, all broken up in box,

dsky grn sh hrd blky ip fis ip,

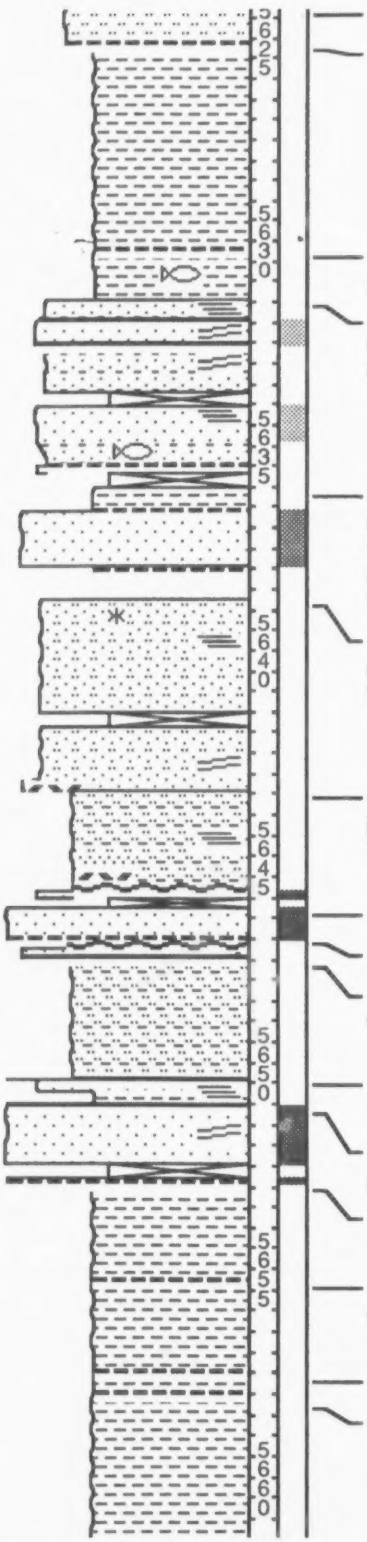
mnly grsh grn sndy (fg) sh w/ scat patches near base of drb. one 2cm upmg ss bed approx 15cm from top, vry soft in btm 18cm where drb exists.

fg-mg ss mass - conv

intbd - intlam fg-vfg pl grn ss w/ grsh grn mud & blk specs , wvy disc,
sndy ip and shly ip

intbd - intlam fg-vfg pl grn ss w/ grsh grn mud

dyb mg ss low > bdng horz above missing core



grsh grn mas slst w/ one 5cm central area with abnt sand

drk rdsh brn hrd blky sh, brec appear w/ grsh grn at base

grysh grn hrd blky sh w/ sparse fish scales and bones, scat peb & grs

fg unit w/ mostly horz lams in a dyb shly ss, scat mud lams up to 1/2 cm at base but most are 1-2mm. mg ss lag. fish bone found in muddiest unit just above lag.

From here to base of core is scat pieces of rubble caution!
Upper & Mid sh is grsh grn hrd blky
SS is pl ysh brn mg ss w/ faint low > bdng.
Lower sh dsky rd hrd blky

drb-grysh grn slty - fg ss, thin beds 1-8cm of changing climbing rip, horz, low >, capped by a massive slty - fg ss. Base is a mg ss with abnt mud clasts giving a brecd appear.

mainly drb w/ scat grysh grn patches, brec appear at base, disct approx horz lams seen by color changes, sndy ip

pyb vcg ss, crumbly, bdng not visible

2 fin up seq w/ mg lags up into grysh grn slt

mottled drb grysh grn slty sh, long 8cm vert frac 20cm from top

intbd mod ysh brn fg ss w/ dsky grn sh and shly snd. bds 1/2-2cm

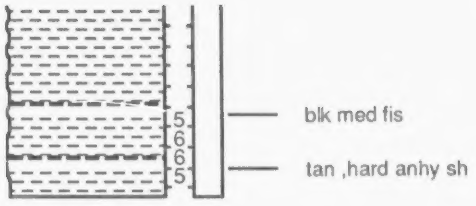
upper med-crs gr ss, scat peb throu,cmtd @ base and patches throu, faint low > bdng throu

mixed grysh grn and drb hrd & blky, horz lamd ip

dsky grn very fis med, broken up into little pieces through,wxy

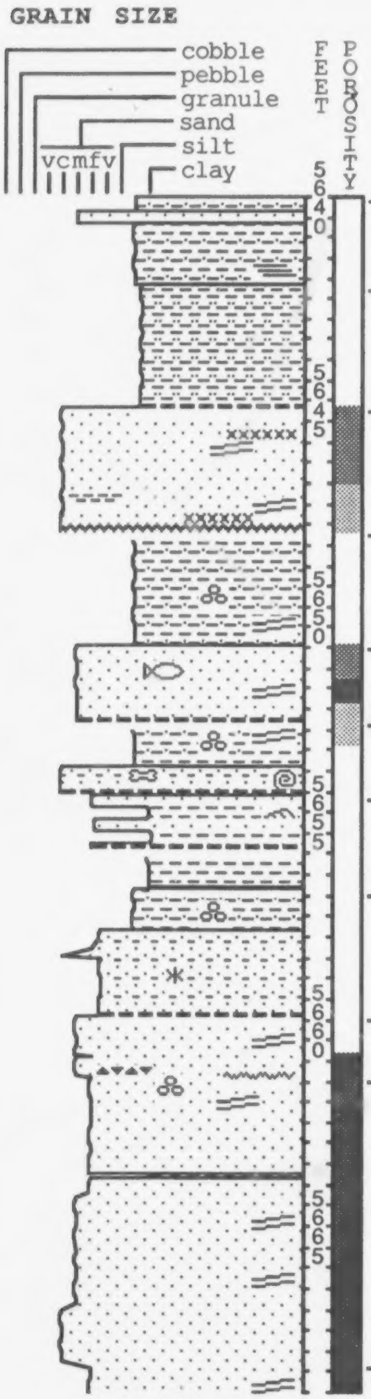
blk sh mod fsl

vgtd sh lamd and conv


blk med fis
tan ,hard anhy sh

Shell et al Nipisi

10-27-79-8w5



core is mostly broken up depths may be out, not sure where missing core
lamd sndy sh is pyb w/ low > - horz bdng, slty sh is ol gry hrd blky

ol gry slty sh, mass,

pyb cg ss, well cmtd throu, low > throu, muddy lams in bot half,

grysh grn sndy sh, scat limy clast, lamd snd & sh @ bot w/ low > bdng.

dyb mg ss, low angle bdng through, bones, cmtd crsr bands

shly cg shly ss in lower half of unit w/ mud clasts 2x2cm, fish bone, and limy clasts, upper unit a sndy grysh grn sh w/ few scat limy clasts.

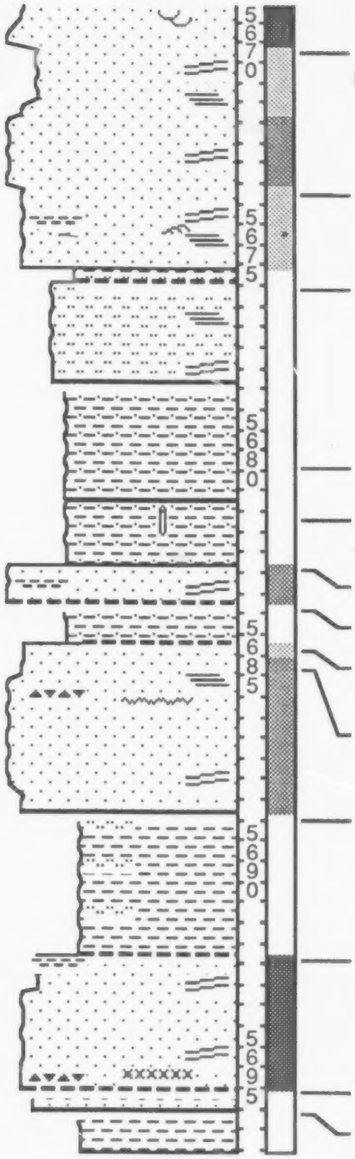
intb-intlamd, fg ss w/ grysh grn sh, current and climbing rip.

top of vcg muddy ss, in upper 13 in contains scat limy clasts (more dense just above the fg unit and more scat in upper part of whole unit

pyb mg ss, low angle bdng

pyb ss, fin up, scat sh lams & thin 2cm sh bds, very few limy clasts in upper 6 in of unit.

pyb fg ss, trough in center, low-high angle @top,



pyb mg ss, grysh grn fg, fin up, mainly low angle lam-horz bdng

pyb fg ss horz-low angle bdng, muddy ip, pos cur rip

drb-grysh grn slts, low angle bdng, mainly horz bdng.

vert frac grn inside brn out

unknown burrow extending down from a firmground, w/in a drb sndy sh

pyb ss f-cg, muddy ip, low angle lams

drb-grysh grn sh, sndy ip, sh very fsl

dyb f-mg ss fin up, mainly low angle bdng in lower half, more mas toward top

fg ss, well sorted, bdng hard to discern

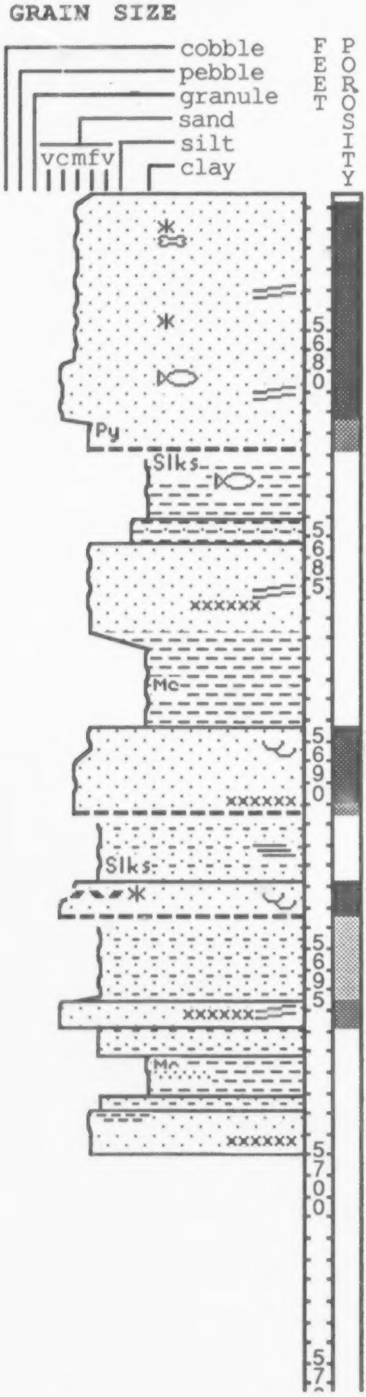
drb slty sh hrd blky, upper 7cm is pl grn

dyb cg-fg ss, fin up, cg bot 9in cmtd, low angl lams throu upper 6cm is fg ss w/ thin 2mm mud lams

pl grn slty sh, fracture

tan-gry hrd blky sh

Amoco Unit No. 121
4-28-79-8w5



drk ysh brn mg ss. faint low angle bedng, generaly mass in appear

peb bed w/ large mud clast (6cmx4cm) psbl fish bone, no bdng vissible

ol gry sh @ base with abnt fish plates hard fsl, bcmg dusky grn hrd blky at top, with slks.

grsh grn sndy sh

pl ol-pl ylsh brn mg ss, with irreg cemtd areas ,well sorted

mixd & mot drb-grsh grn med sl fsl sh very mic ip, grsh grn @ top

pl ylsh brn mg-fg ss, cmtd @ base, trough throu. fining up

intbd-intlamd mg pl ylsh brn ss w/ grsh grn sh, some sh is mod fsl w/ slks

pl ylsh brn crs gr-mg ss fin up. mud clasts in upper mg ss

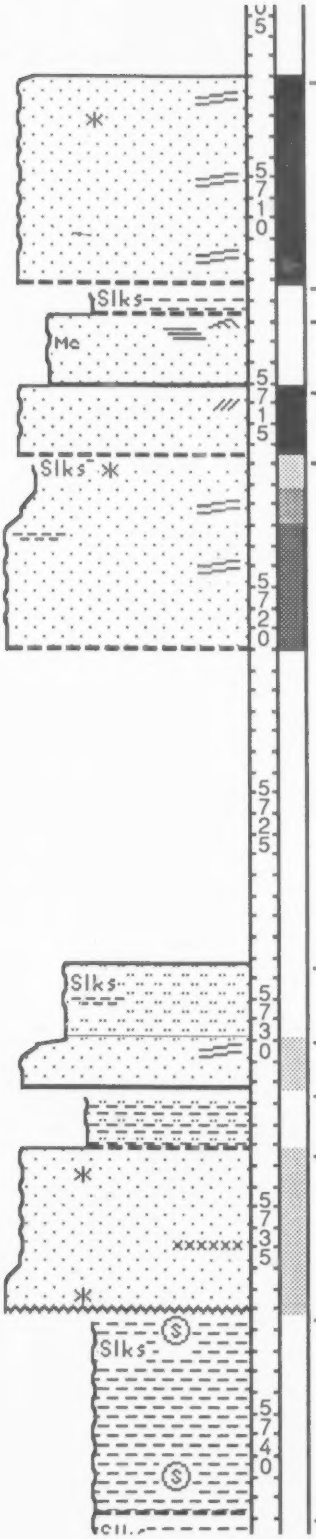
pl grn shly ss med gr w/ abnt crs gr. sndyr ip, shly ip.

grsh grn shly fg ss, low > - rippled (could be just disturbed), becmng drb and shly toward top.

drb-grsh grn soft fsl sh very mic, sndy ip

mixed drb-grsh grn sndy sh

shly pl grn mg ss w/ scat pbl and crs grns. broken up in box. cmtd ip



pl ylsh brn-drk ylsh br [illegible] d-lcrs gr ss. well sorted w/ subrounded -rnded grns. f [illegible] ow > bdng @ mas in appear, upper 7cm is a fg lamd ss [illegible] d w/ ss below

drb med fis sh, abnt slks

vfg lamd ss , pl ylsh brn-grsh grn, mainly horz lamd w/ cur rip at base @ indeter rip in upper 10 cm (may be just desturbed bdng., scat peb @grns ip, very micaceous throught.

cg ss w/ abnt pbls, faint high > bdng seen in few disc cemt horz

pl ylsh-drk ylsh brn ss, cg-fg fining up, cg ss contains (thin sh bds 1cm, mud clasts and scat peb), low > bdng throu, fg ss is pl grn @ mass
getting muddier towards top, slks in uppermost shlyr part

drb sltst, grsh grn @ base, sndy ip shly ip w/ slks, mot drb grsh grn @ top

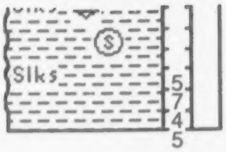
pl ysh brn mg-fg ss w/ cg cmtd bds, pos low > bdng, mud clast (3x2cm)

slty sh drb @ base & pl ol near top, scat micro frac

dyb crs-mg ss w/ scat pl ol cmtd irreg patches, mainly mass, fair sort

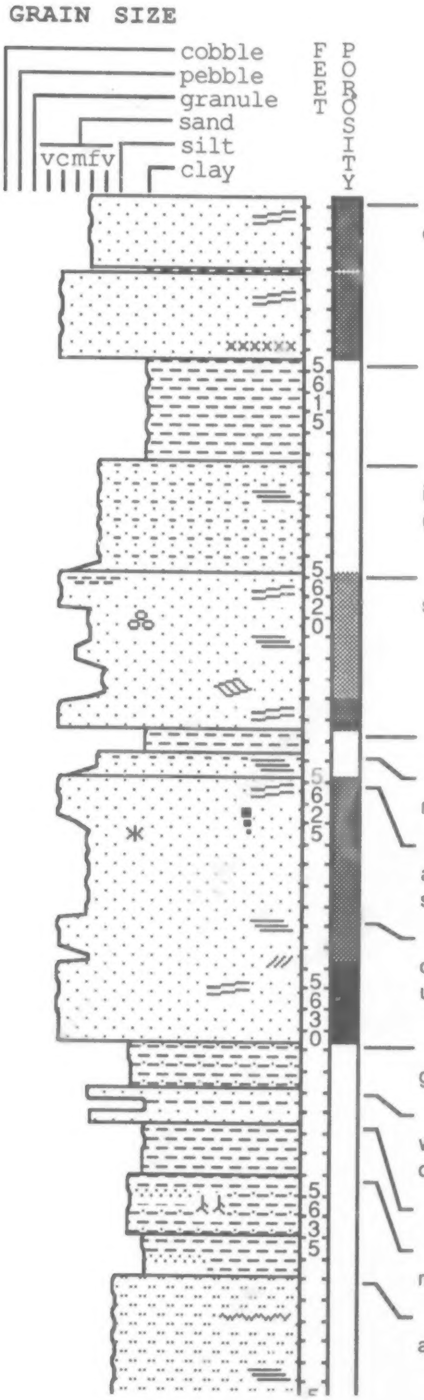
mainly drb med fsl sh, brec in appear, slks and micro slks throu, some of the grsh grn sh is very waxy,

ntrbd d grn, d ylsh brn , blk sh w/ drb at base. horz lamd



through, scat brac in blk sh

Hamilton Nipisi
2-29-79-8w5



ss mg-fg, fin up, low angl bdng throu, fair sort ip, bot 6cm cemented

grysh grn hdr blky sh

fg shly ss w/ abnt scat crsr grns throu, ss content increases up, lower half is grysh grn with higher sh content (&swelling clays), upper half is more pl ylsh brn

pl-drk ylsh brn ss, 3 fin up seq. cgrss (low angle bdng), fg ss horz lamd with pos climbing rip

broken up pl grn hard blky sh, sandy ip.

dsky grn shly fg ss, horz lamd, few 2x1cm calcite clasts, mic

fg ss is pl - drk ylsh brn, its mdy ip making it pl grn, mas in appear but bdng hard to discern, appears to crsn up to cg ss with low > bdng

crs gr ss w/ mainly low > bdng, a thin 5cm fg unit & 5cm of crs gr above that shows high > bdng, upper part of crs gr unit is horz bdd

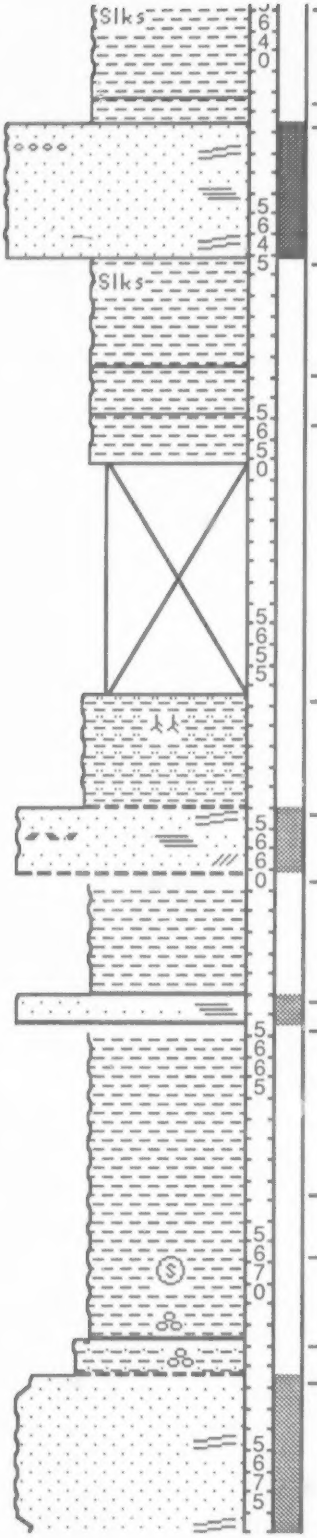
mixed dsky rd- grysh grn sh, mic ip, sndy ip, upper 6cm is grysh grn.

intbd pl ylsh brn fg ss w/ pl grn med fs [illegible] ss is horz lamd w/
occas wtr escape struc

mot drb-dksy rd soft-med fis sh.

mot dsky rd and dsky grn sh, v sft and fis throu, becmg more sndy up

drb horz lamd sltst., scour is by more sltst, scat pl grn areas throu



dsky rd hrd blky sh, scat mic bds, 2 slks in upper 20 cm

pl grn hrd wxy sh

dyb crs gr ss. bdng hard to discern, one peb horizon 6cm thk10cm from top

mot dsky rd-grysh grn sh med-hrd blky, scat slks

dsky grn hrd blky sh slightly fsl

ol gry hrd blky sh

grysh rd slty - sndy sh w/ abnt pl grn branching root like struc

mainly mg ss with rapid changes in sed struc, main units from base up are high angle bdg , horz, low angle w/ mud clasts, faint low > - mas

dsky rd very fsl sh at base bcmg drb up. top 6cm is grysh grn hrd blky

pl ol mg ss w/ abnt fg parts, many stacked beds with horz bases & no internal bedding visible

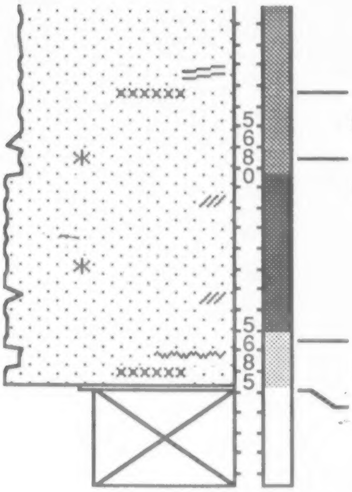
dusky rd med fsl sh, brec in appear ip, sndy ip, and pl grn ip, some long 15cm frac (some are pl grn inside others drb inside), upper 13cm is grysh grn hrd wxy sh in contact w/ ss above

drb hrd blky sh, few pl grn root like struc near top

dsky rd sft fis sh, abnt microslks, 3 limy blebs near base

intb pl grn & drb sndy sh, sh is soft fis & mic, few scat limy blebs

mainly mg dyb ss w/ faint low > bdng, mass appear ip



irreg shaped cmtd horz, 5 blk sh-mud lams w/ scat crsr grns

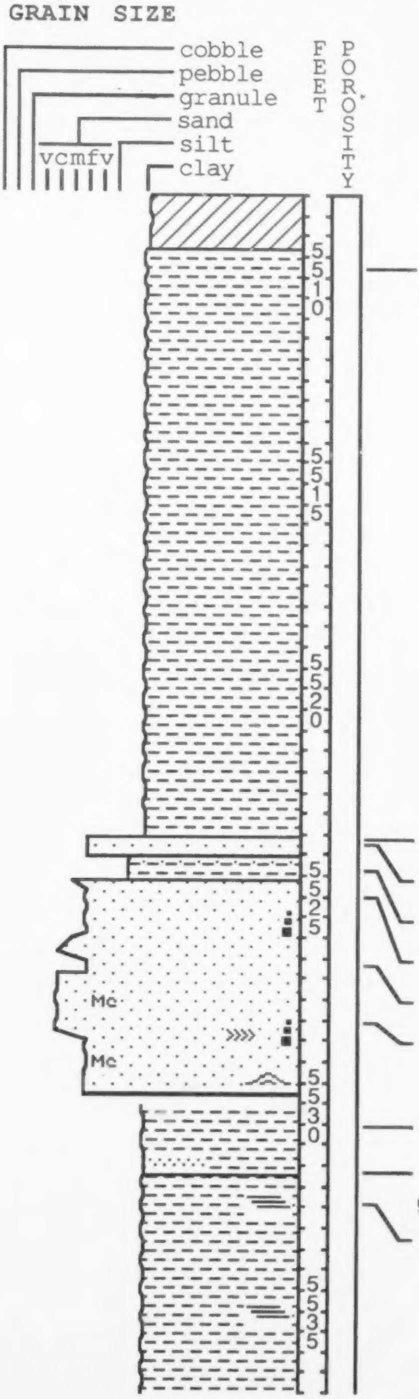
dyb mainly mg ss w/ high > bdng some smaller bds 2-5cm of fg mass

two minor scours below here w/ crs gr lag, cmtd @ bot w/ high > bdng

pl grn hrd blky sh, scat ss grns

Cairn et al Nipisi

2-5-80-7w5



brn sh, bcmg grn towards base, v blky, becomes fsl at base

1cm mg sand with micro mud drapes

gry fg sand with grn sh lam, med angle x-bd

fg sand floating in a matirx of soft, friable grn sh

tan-gry sandstone, fining up

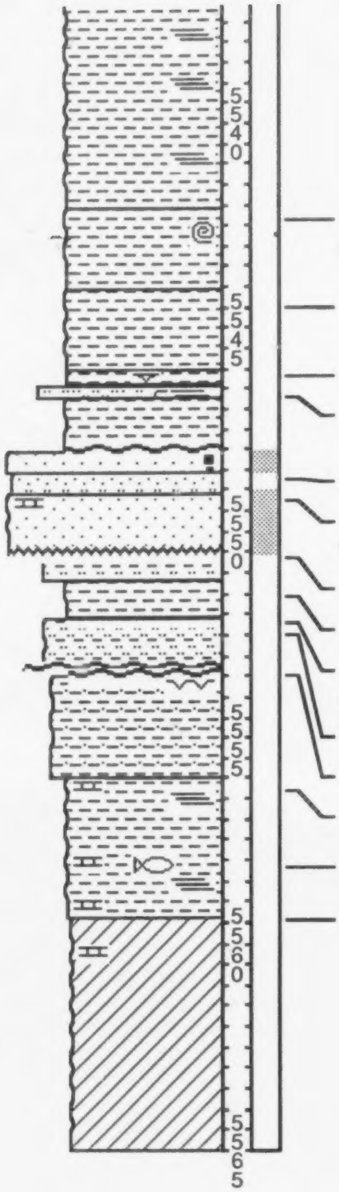
very coarse bed (5cm) very feldspathic

coarser bands appear to be fining up

med grn sh, hd, thn hz bdng

thn (2cm) sand bed, med grnd, with scattered course grains

red shale, hd at top bcmg sft & friable at base, v thn lamd



red shale with abnt tan mud lam, lam are very contorted, abnt slickensides

med grn, v soft, occ slickensides

dark grn, friable, abundant lingula

dsky grn sh, silty lam (.5-2cm) throughout abundant lingula brachs, possible planolites

pl grn cg sand grains in a silty matrix,

4-5 coarsening upward sequences (3-8 cm) thick, thickening upward

floating red clay clasts below contact

drb very fsl shale

silt grains in predominately shale matirix mottled appearance

large mud clast (6cm x 10cm)

microfaulting ,and mud cracks infilled partially w/ calcite

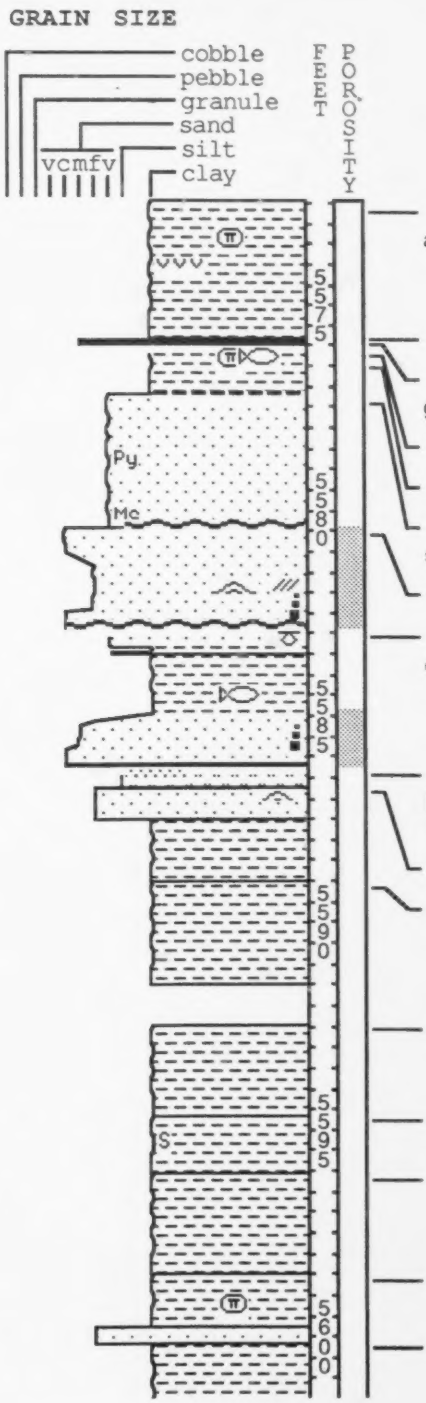
dark brown shale

scattered fish scales and armour fragments

Contact w/ top of Muskeg

Amoco Unit 378 Nipisi

2-6-80-7w5



dsky grn sh, med hd, fsl in part,few scat fish scales, anhy clasts (2x1cm) scattered from 1699.7-1699m

blk sh 1cm thick

mg ss bed (3cm), lt gry, upper cm coarser(not gradational)

scattered lingula, and fish armour fragments

dk grn sh,v fissile

grysh grn ,reddish towards base, vf sand,argillaceous, sctd coarse grains, minor slickensides

lt gry to buff mg ss, scat peb (1cm), high < bdng

med grn, sft,fissile shale interbedded w/ vf lt gry ss, scat crs grains

(1-2cm) sand bed,few scattered clasts (1cm) qtz & K-spar

burrow (6cm) infilled with sand as above

v thinly (mm) laminated sand/shale

red shale,massive,hd

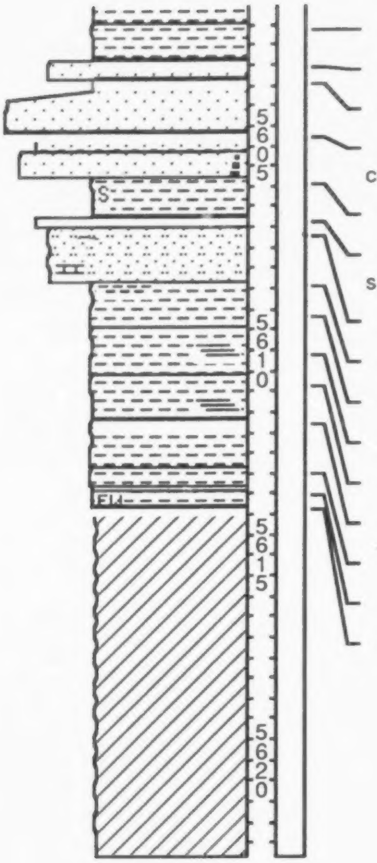
abundant slickensides 1705.7 - 1706.2

lt grn sh, blky, rubbled,minor slickensides

drbsh w/ some grn mottling ip,hd,massive

grn sh, sft,v fissile,scattered fish scales

dk grn w/ dispersed red mottling



red shale,med hd,fissile,mottled with grn sh in part

lt grn vf ss,sctd fine grains 'floating' in matrix, fg lag

med grn sh, fissile,sft

greenish shaly fine sand w/ coarse sand lenses,2x1cm calcite clast

purple shale, abdnt slickensides,hd

6cm zone of interbedded fine/medium grnd, red and grn sand

reddish grn,vf sand, 1 mud clast (2x3cm)

grn sh, soft, fissile w/ blk sh intbds

tan mudstone

massive lt grn sh w/ occ red lam

inerbedded grysh grn (cm) & red (mm) shale

dk brn,hd, slightly laminated, top 5cm lt brn, sl slty

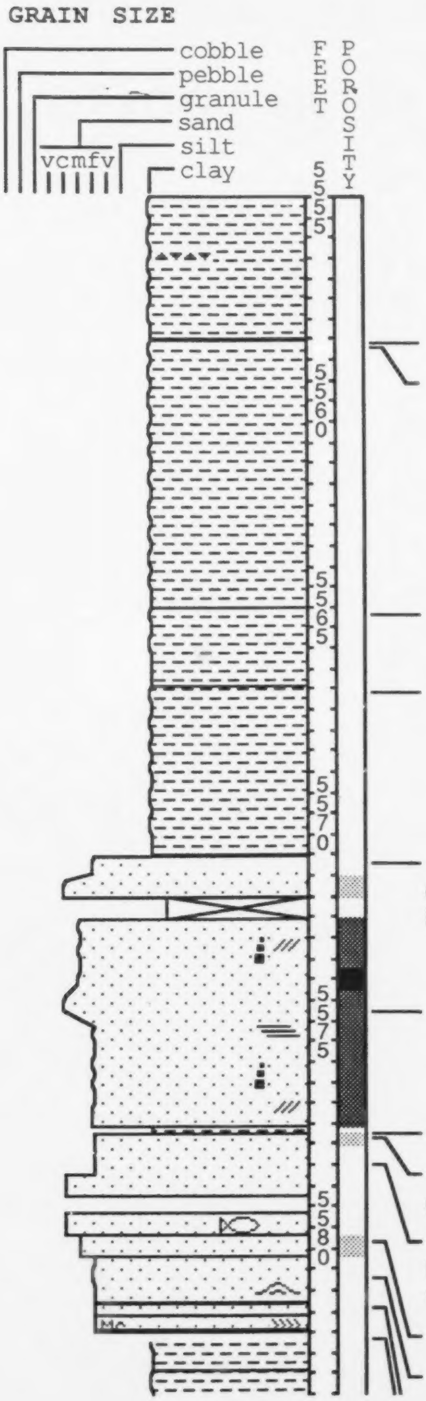
blk,soft,fissile

lt brn massive sh, sl slty, 1 k-feld clast (2cm)

thin (2cm) red shale above contact

Uno-Tex SOBC Nipisi

12-6-80-7w5



contact mkd by sh bcmg laminated with tan/brn shales

dusky grn sh,hd massive,sl fsl @ top

grysh grn sh,sft,v fsl

dusky grn sh,hd,massive,sl fsl @ top

pale ylsh brn sand, vcg@base,fining up to rng, bdg diff to discern but ranges from hztl to high angle, some x-bdg @ base

occ feldspar and qtz grains up to 1cm in diam to base

grysh grn, v sft, fissile

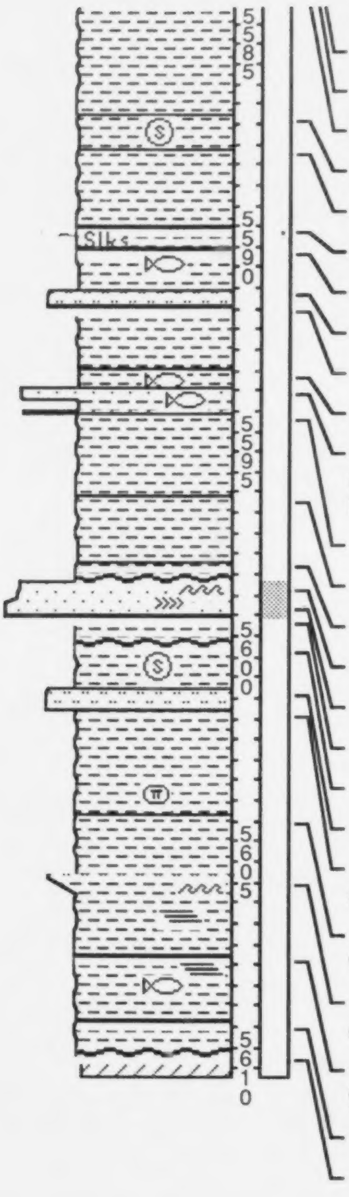
grysh brn ss,fg,mass, possible low > bdng, pr srt @base gd srt @ top

lam SH, blk @ base bcmg grysh grn @ top, hd @base bcmg sft and fsl@ top

w/ SS,grysh olive,cg,poor srt, ss bcms less abndt twds top

dk ylsh brn, mg, massive

grysh ol fg ss w/mnr 3cm sctd fining up brnsh olive



squences

brnsh gry ss,fg,g srt,massive

grysh olive,hd, massive blky sh

dusky rd sh,hd blky ,sl fissile ip

grysh olive sh, hd, sl fissile, mnr slickensides

dusky red, hd blky, massive

grysh olive, md hd,fissile, slickensides

grysh olive speckled w/ dk rdsh brn, hd,mod fsl, scat fish

olive gry sltst,

grysh olive speckled w/ dk rdsh brn, hd,sl fissile

dk grysh olive,sft, v fissile scattered fish remains

grysh grn, lam w/ grysh olive fg ss,psrt some bands of mg ss beds are planar @ top,sl convolute @ base, 2 blk lams(1-5mm) at top

ol gry w/ drb, bcmg ol twds top, hd blky, sl fsl

dusky rd,hd blky sl fissile

grysh grn sh,hd blky, sl fsl,sctd feld grns (up to 4mm)

grysh olive ss, fg ,vpsrt ,sl convolute bdg at top

pale ol ss w/ abdnt k-spar,mg vpsrt, high > x-bd at base

grysh olive sh, hd,sl fissile

dusky rd sh, md hd, sl fissile, mnr slickensides

tan sltst w/ thn (2mm) grn laminae

dsky rd sh,intrbd w/ occ dk grysh ol &dk brnsh rd sh v sft,fsl, mnr slks

dk ylsh brn mud(3-7cm),dk grysh olive sh (1cm),hd thin(.5cm) grysh olive sft sh bed at top

vgtd grysh brn,pale ylsh brn,dk rdsh brn&grysh ol sh gtng dkr twds base

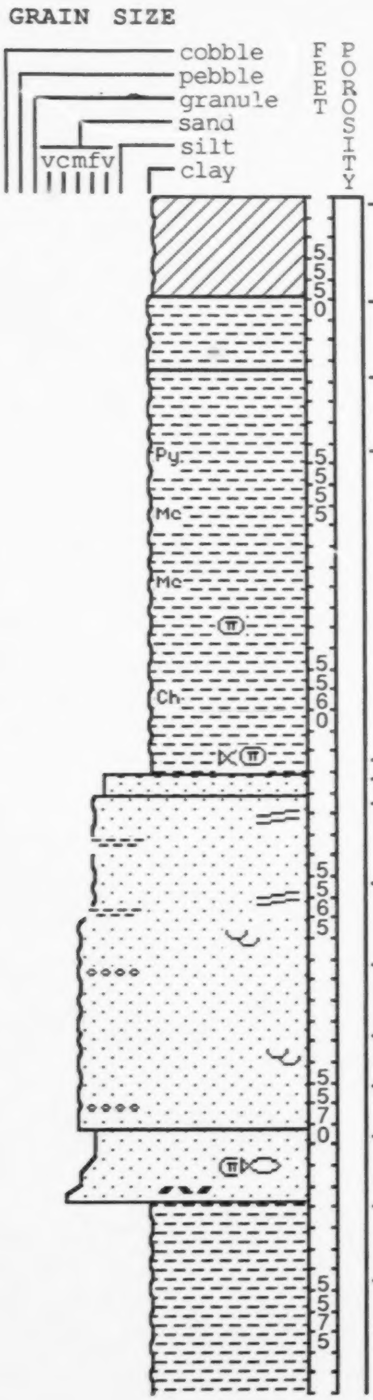
dk blk sh, hd blky , v fsl at base bcmg more blky at top, fish remains

pale ylsh brn sh,hd blky, thin(1cm) grysh olive sft sh bed

Top Muskeg Anhydrite

Uno-tex Nipisi

12-18-80-7w5



drk brn horz lams anhy

gry-blk sl fsl sh,

solid piece psbl anhy sh, dsky grn-gry-brn, very hrd

grysh grn - gry blky - sl fsl ip sh, fish scales and plates assoc w/ fsl sh

grysh-pl grn sft very fsl sh w/ abnt scales and plates

fin up seq, basal 3 ft half mg half cg ss, crsr gr bds cmtd, abnt scat peb,mid mg ss has less crsr bands and peb (trough throu these two zones) thin pl grn sh 2cm before upper fg unit, low angle bdng, shly ip, upper 25cm intbd f-cg dsky grn sndy shss 5cm w/

cp 1-3

cp 4-5

cp 6-7

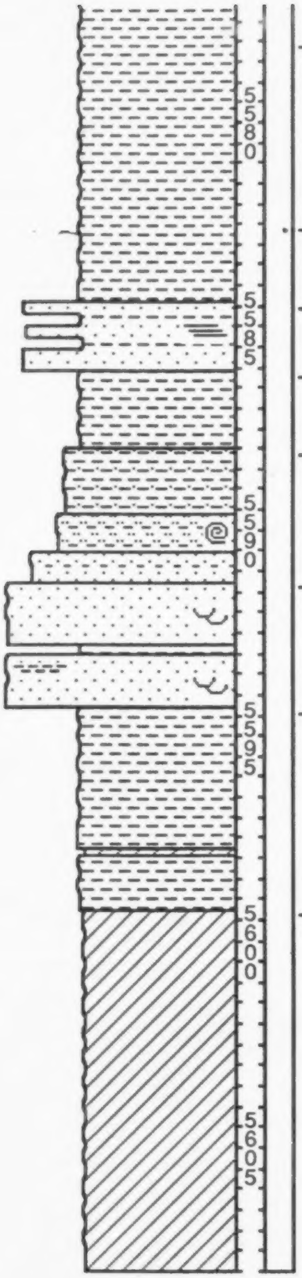
cp 8-9

cp 10-11

intbd ss sh, ss bds decr in thickness and gs up, basem-cg, fg @ top, fish plates and scales found in center of unit, sh is grysh grn med fis

grysh grn hrd blky sh, broke up so contact w/ lower drb ?

dsky rd hrd blky sh fsl on edges, scat grysh grn patches



core broken up, mod hrd blky fsl on edges, absorbs wtr fast, decr amts of grysh grn up, mainly drb

drb very dense irreg wormy mod hrd blky sh, wormy text produced
by grysh grn

intbd ss-sh, ss is mainly fg but few scat mg-peb, sh is dsky grn sft-hrd, bds ard not always continuous but approx horz,bdng scale of .2-2cm

gry hrd blky sh, fsl on edges, scat drb patches.

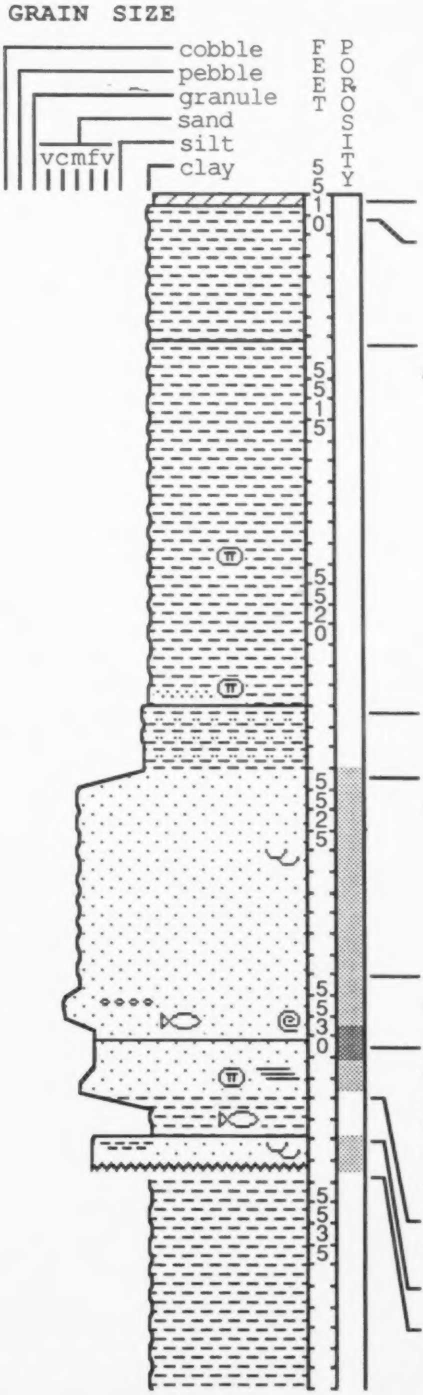
irreg patched mixed drb-pl grn sndy sh @ base, slty sh mid, sndy sh @ top, upper 20cm is mainly drb & brec.

mg ss mainly trough, w/ few sh inrbds @ base
bx 12 cp12-13 bx13 cp 14,15

vgtd anhy sh, mostly grysh grn-gry w/ scat drb, yel, and tan anhy

solid tan anhy

HBBA Nipisi
10-19-80-7w5



drk brn horz lamd anh sh, calc

drk grn brn gry, hrd blky sh w/ scat small cm anhy zones.

dsky grn mod blky sh, always md fis - soft around scale areas

pl-slightly grysh grn massive slty sh-sltstone

difficult to make out bdng, pos trough, definate fin up or dec in amt of pbls up, cmtd crsr bnds throu

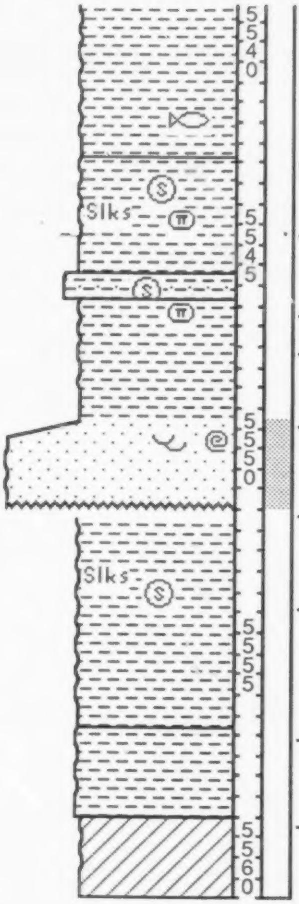
extrem var in gs, psbl truogh bdng but more likely convoluted, scat pbls throu, abnt plates @ base of cg ss

intbd ss w/ sndy sh @ base and ss w/ sft fsl sh @ top,grad contact from below, lower ss bds are mg poor sorted up to 6cm thick, upper ss is fg well sorted up to 7cm thick, abnt fish plates w/in lower mg ss. bdng is horz-wavy through, (12cm base of ss above is same as this upper fg ss and contains sm .5cm mud clasts, is low angle bdd)

grysh grn med-hrd blky sh fsl on edges, abnt plates @ base,

mg ss trough throu w/ abnt sh lams & bds, cmtd throu

mainly med -sft blky sh fsl ip, scat grn worm patches decr up, upper 15cm is pl grn hrd blky



med - sft blky sh, finly mixed drb-grysh grn sh, slks & microslks, very irreg wavy circular texture in center of unit

grysh grn sft fsl sh w/ scat drb patchs, abnt scales at basal contact, hrdr in sndy part w/ abnt slks and microslks above sndy part

gry hrd blky sh w/ strange small scale wormy drb features throu

brec drb hrd blky sh, basal 12cm is grysh grn - pl grn.

fin up seq, mg-fg ss, psbl trough or convoluted bdng throu, gradational contact w/ above grysh grn sh

varying sh, bat 20cm very fis abnt slks and microslks, 6cm mixed pl grn sft sh w/ tan anhy, upper 37cm mainly drb hrd blky sh w/ one thin 1cm tan anhy bd, vgtd w/ pl grn upper 15cm, and 5cm only pl grn med hrd blky sh at upper contact

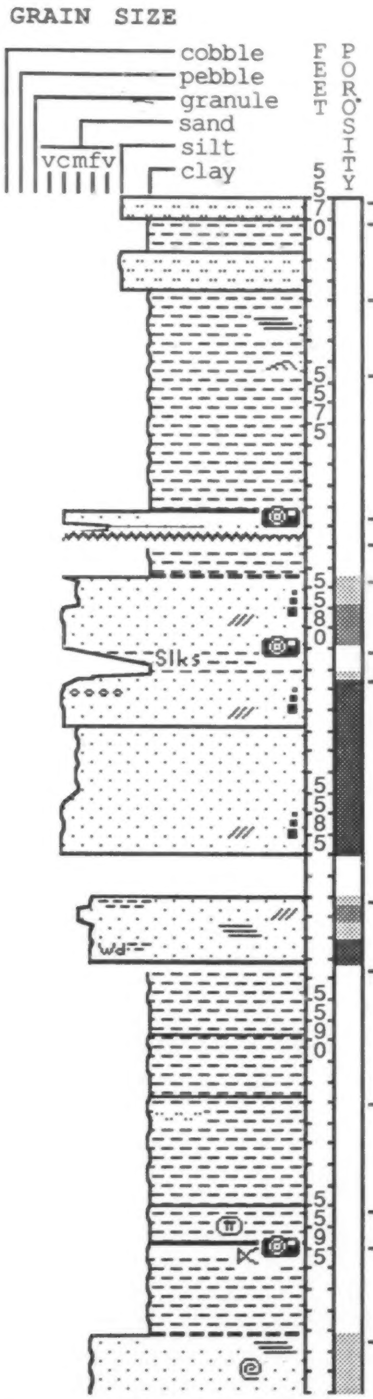
tan anhy sh, slty

blk fsl sh bot, drk grn w/ anhy clasts @ top hrd blky

tan anhy sh @ base pure anhy gry @ top

Hamilton Uno-Tex E Utik

10-1-80-8w5



dk ylsh brn sltst, similar to sltst below

dusky grn to med gry ip SH, hd,laminated v fsl &sl fsl ip

current ripples over 30cm,lt gry vf ss interbeds (2mm)

four distinct layers sep by thin (.5-1cm) blk sh; 1(8cm) mg SS(5cm),occ fltg pbls,grysh grn sh-slt(5mm),churned; 2(3cm)vfg planar lam SS; 3(4cm) mg SS current ripples;4(3cm)cg climing rples capped by mg hznt lam

grysh grn hd @base bcmg v sft @ top, scat crs grns , slks

dk ylsh brn SS,high angle @ base bcmg massive twds top

grysh grn,dusky rd SH,v sft, fsl,slickensides

dk ylsh brn SS, two fining up squences, high angle bdg in cg bcmg massive in fg ss, upper sequence grades into grn mud

dk ylsh brn ss,fg @ base,mg @center,faint high angle bdg ,mdy @ top ?core box may be out of order

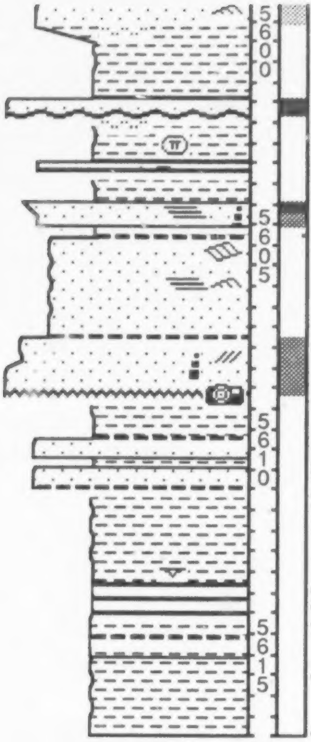
dusky grn bcmg grysh grn @top,hd sl fsl

dusky rd SH,hd,mod fsl ip,sl slty ip

dusky grn SH,hd,sl fsl,sctrd fish scales

intbd dusky rd & grysh grn SH,v sft,v fsl sh,tr slks,abnt fish frags

brn SS,fg,tr current ripples @ base,parallel lams center, 5cm distbd zone w/ red sh &anhydrite clasts 30cm down,



parallel bdng to top

dusky rd SH, hd,sl fsl bcmg v fsl @base, grnsh @ base, slty @ top

dk ylsh brn olive ip SS,cg

intbd grysh grn & dk rdsh brn SH w/ dk ylsh brn mg SS,

grysh brn ss,vfg,v well srt,bcmg sl shl @ top; climbing ripples @ top; intbds of near planar beds and current ripples w/sl finer dk ylsh brn ss in the center; stacked sets of current ripples bottom 40cm

dk ylsh brn ss, c-mg vp srt, med-high angle bdg,fining up

dk rdsh brn,and grysh grn sh

dk ylsh brn ss,fg, thin (<.5cm)grysh grn sh lam,massive w/sl convolute bdg

grysh grn sh,hd,fsl(8cm)

dk ylsh brn fg ss churned w/grysh grn sh

intbd drk rdsh brn,dusky grn,grysh olive shales,v fsl to sl fsl @ top tr lingula

lt olive gry mdst intrbdd w/ blk sh

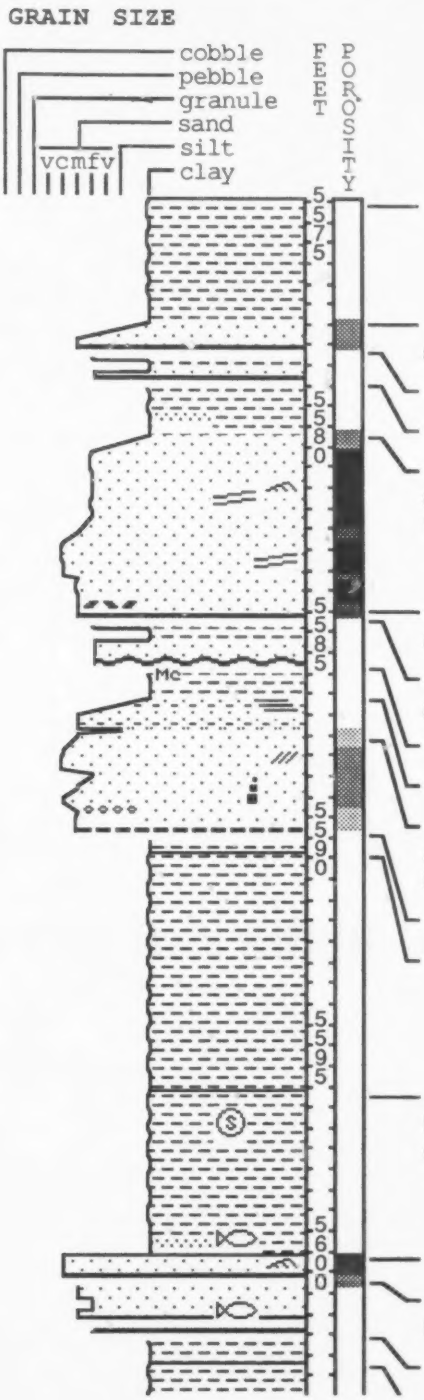
dusky grn sh, sl sft,fisl

lt olive gry mdst lamd w/ dk gry sh @ top&base, mdst appears 'clast-like' in center,possible fluid escape features?

intrlamd grysh brn,pale ylsh brn,drb &grysh olive shales

7cm blk sh @ base

Amoco Unit 320 WIW Nipisi
12-1-80-8w5



grysh grn SH,hd blky, sft fsl @ btm 5cm

mod brn mg SS, pl ol @ cntr, scat qtz & k-spar pbls, sft grn mud clasts @ top

intrbd sft grysh grn SH w/pl olive fg SS,psbl ripples

ntrbd dusky grn dusky red SH,v sft, v fsl

mod brn & pl olive SS, colour varies throughout due to oil stain, current ripples: abndt mud clasts & lam @ top 10cm,dewatering?

mud clast at base 5x5cm?, scattered smaller (5mm) above

intbd fg pl ylsh brn SS w/ dusky grn SH, bdg is contorted psbl ripples

dusky grn SH,v sft,v fsl,micaceous,few sctd crs grns

v muddy SS, grysh grn & dk ylsh brn,

pl ylsh brn & pl olive SS, cg ss is pl ylsh brn & has high angle bdg, fg ss is mass w/ abdnt fltg crs grains in matrix @ base and top

dusky grn SH,mod hd blky, sl fsl

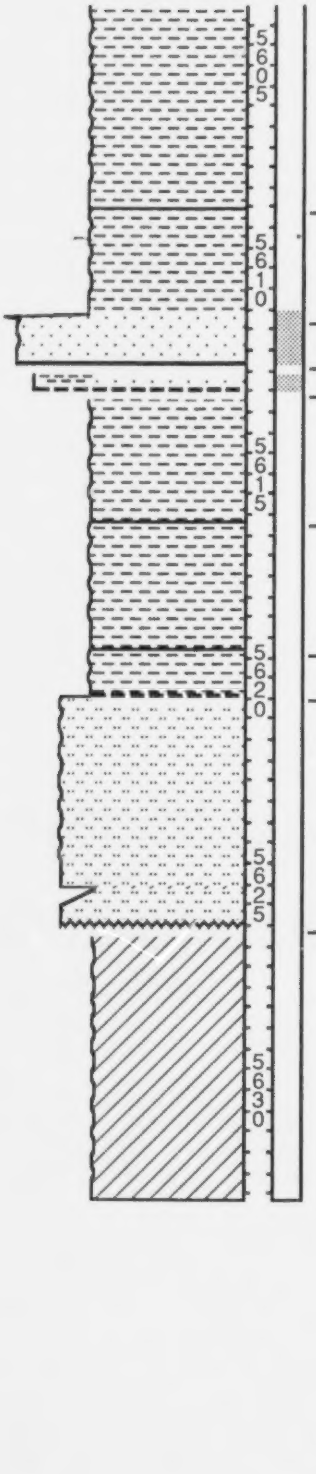
dk rdsh brn, dusky rd grdg SH, hd blky, cntr mod fsl

mixed dk rdsh brn & dusky grn SH, few small slks,hd blky, sl fsl ip few fish remains @ top : btm 10cm has sctrd 1 cm ss lam, psbl fish bones

grysh brn s&p SS, cg, current ripples(trough x-bdg?)

mod ylsh brn SS intbd w/ sh as below, v well cmtd, psbl frag bone

grysh grn sh, hd blky, massive



dk rdsh brn SH, hd blky,massive, mod fsl btm 40cm

mixed grysh grn & dusky rd shales,v hd blky

mod brn S&P mg SS units 2-4cm thk,sep by dkr mud lams 5mm thck, (.5x1cm)anhy clast, top 5cm is crsr and grnsh (out of place?)

pl ylsh brn fg SS,sl churned with grnsh mud,more mud twds top,crs grns @ base

mixed grysh grn & dusky rd shales, v sft & fsl @ base,

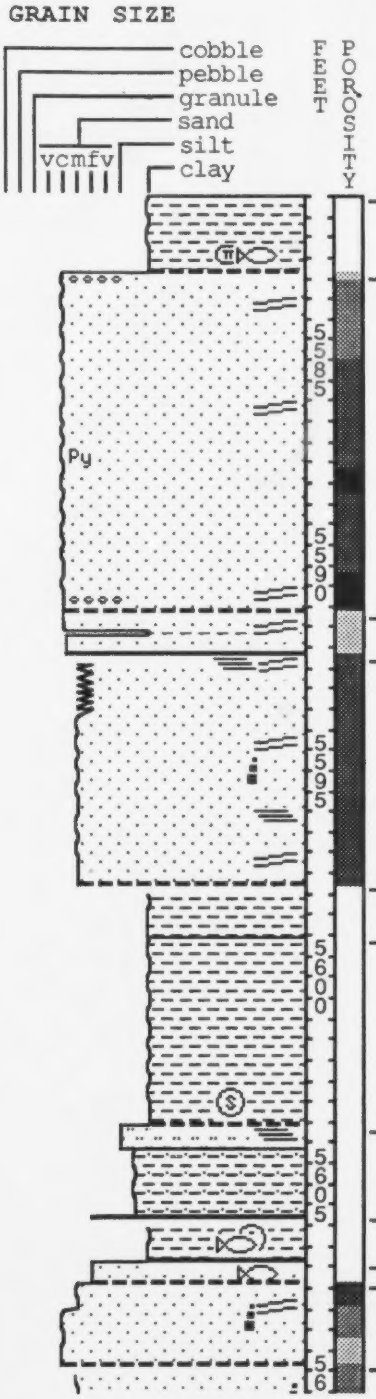
pl ylsh brn w/ dusky grn lams,'clast-like' appearance ip; top 14cm (1-2cm) blk sh lam;
btm 40cm:ntrbd dusky grn, drk rdsh brn, pl ylsh brn shales,sl convoluted bdg top to parallel @ base

blk-v dk brn SH,v fsl, hrd blky ip

tan SLTST(mud??anhy??),massive,v well cemented, 1 gry anhy bed (1-2cm), 30cm fr base w/ abdnt medium anhy grns floating in matrix dcrsg upwards for 30cm

Top Muskeg Anhydrite - contact scoured w/ anhy clasts @ base of sltst

Amoco NGU Unit 293 Nipisi
10-2-80-8w5



dusky grn SH,hd blky - v sl fsl, fish remains @ base

dk ylsh brn cg, p srt SS, pbls @ base, cmtd crsr grain bands, low angle & planar (trough x-stratified?)

pl olive SS,cg w/ abnt pbls(qtz&k-spar mnr calcite); intbd w/ dsky grn SH, 5cm @ center,rmdr <1cm thk, low angle bdng

dk ylsh brn m - fg SS, crs grns&pbls sctrd throut mg, planar & low angle bdg throu

dusky grn SH, blky massive

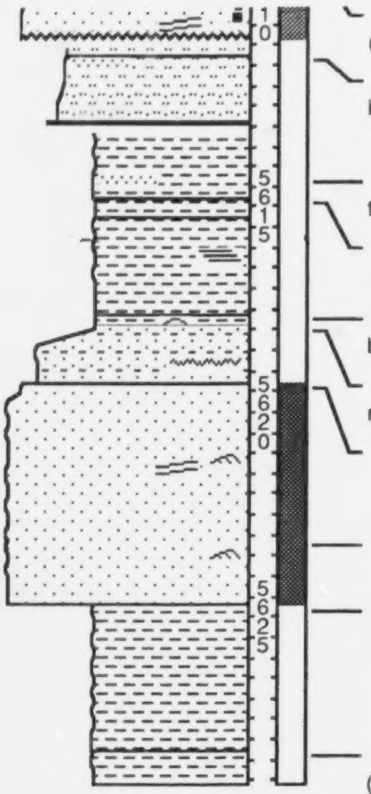
dusky rd SH, hd, sl fsl ip, grnsh twds base,small slks @ base

mixed grysh grn to dusky rd SH w/ pl ol fg SS, SS bcmg more abdnt & intbd twds top,~ parallel lams,sh bcmg dk gry @ top

dk gry SH,mod hd,v fsl, armour/scales/teeth?, small slks

intbd v pr srt(pbls-fg) SS (1-2cm thk) w/ grysh grn SH; hzntl lam, abnt psbl bones

dk ylsh brn SS,cg-mg,fining up,v cs @ base,low > planar bdng



dk ylsh brn mg SS,fining up,crs grnd lenses (1cm) every (3-5cm), top 10cm disturbed w/ sh clasts

grysh grn & dsky rd SLTST,hd,mass, 5cm mg SS as below 15cm fr top.

grysh grn &dusky rd SH, v hd, mass, p srt SS zone (5cm thk),

dusky rd SH, hd mass, w/ few sctrd grn sh bands

dusky grn SH, sl fsl,mnr slickensides, grds into a reddish brn sh

pl olive SS,, upper portion has several minor scours w/ mg-fg, fining up sqncs,sep by 1mm mud,

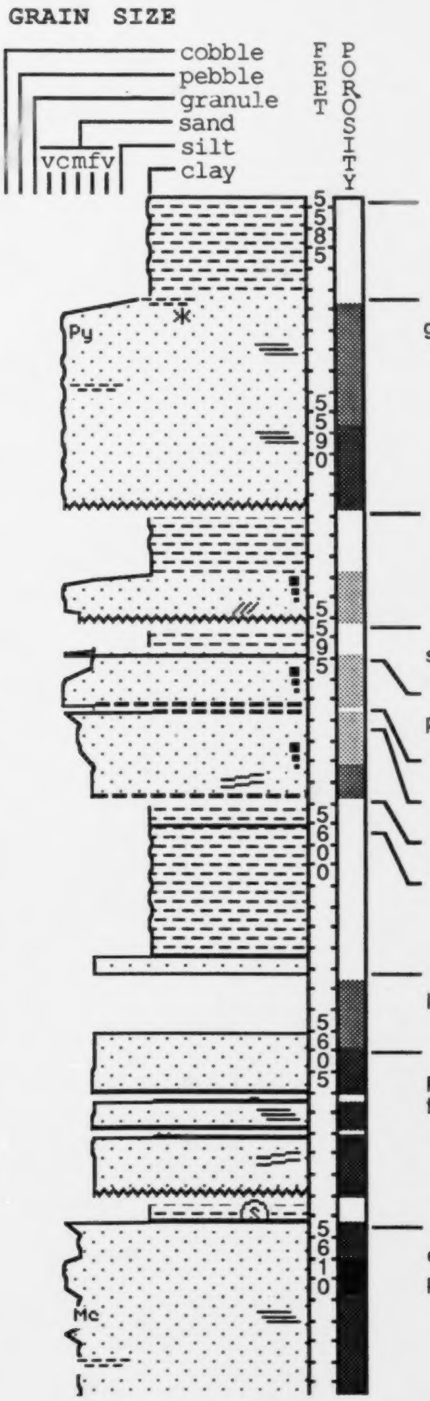
dk ylsh brn, mainly cg SS, generally fining up (v pr srtg)

cg SS w/ crs &fg lenses (2-5cm), faint current ripples

mixed grysh grn & dusky rd shales,mod hd, sl fsl

pl ylsh brn mdy SH (1-2cm) w/ blk sh lam(1-2mm); (entire box was rubble)

Amoco Unit 264 Nipisi
12-2-80-8w5



dusky grn-blk SH,v hd blky

dk ylsh brn cg SS, mass bcmg v mdy @ top w/fltg vc grns,hzntl bdg?

dusky grn mdy SH, mod hd blky, crs grns @ base,

dusky grn SH,mod hd blky, mass, lower contact has some cg ss intbds

pl ylsh brn fg-mg SS,coarsening up?,mod angle x-bdg, pbls @ top

intbd ss/sh as above (possibly misplaced core)

pl ylsh brn fg-mg SS, coarsening up, mod angle x-bdg

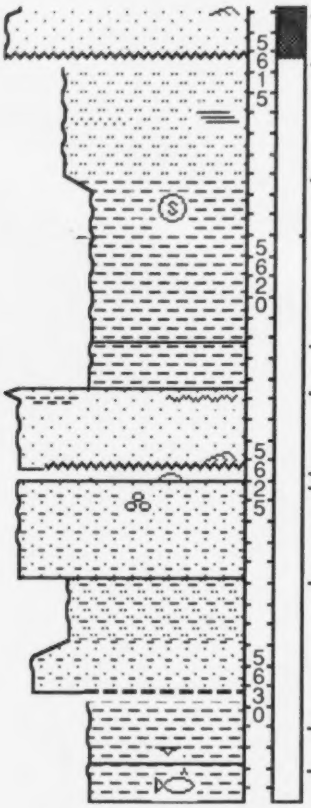
dusky grn SH, hd blocky

dusky rd SH,hd,blocky

SS as below,inbd w/ grn mud & blk sh, planar sub-parallel lams, fish fossil frag, grdg into grysh grn sh at top 20cm

dk ylsh brn fg SS,swelling clay clasts(2cm),low angle psbl (trough?) few intbds of dusky grn & dusky rd SH,sft v fsl, sm slicks

dk ylsh brn SS,cg-mg changing rapidly above 1710.8m, extrmly
prly srtd throughout!!, small current ripples @ 1710.9



dk ylsh brn ss, cg, pbls @ base,v prly srtd, (crumbles @ touch)

pl olive SLTST,v well cmtd,hd,slt size qtz grns in a grnsh clay matrix,few medium grns in 2-4cm zones,massive w/ faint planar parallel bdg, swelling clays below above contact

dusky rd SH,hd blky mod fsl, mnr slickensides

dusky grn SH,mod hd blky ,v sl fsl

pl olive SS,w/ dusky rd bands,extremely prly srtd, mainly mg w/ fg (1cm) bands sctrd thru,numerous sets of stacked sm current ripples @ base bcmg mottled @ top,6cm cg ss w/ scoured base 10cm fr top

dusky grn SH,mod hd blky, sl fsl, sm slickenside

mottled & banded grysh ol & dsky rd SS, mg w/crsr grns floating in v shly matrix, sctrd 1cm calcite blebs throughout

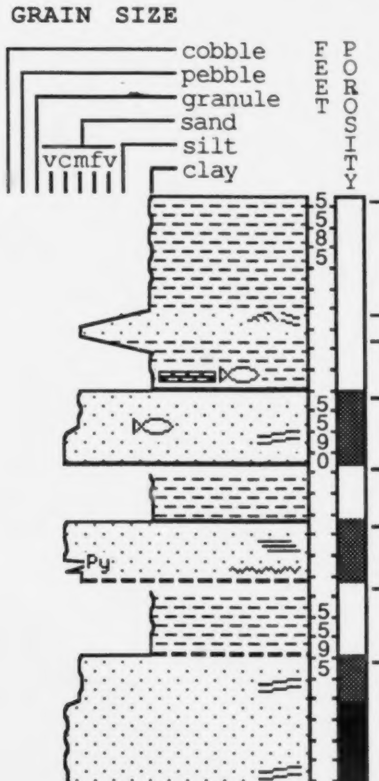
pl ol & grysh ol & dsky rd SS,SLTST,SH; fg ss @ base intbd w/ sh; grdg to slty sh @ top

dusky rd & dusky grn SH, mod hd blky, sl fsl ip, grnr @ top

tan SH(mud?) lamd w/ blk sh;top 10cm all blk & dsky grn sh, (bones)

Amoco Unit No. 193

12-3-80-8w5



dusky grn SH,hd blky

pl ylsh brn mg SS, grn mud lams, psbl current ripples, wavy lams @ top

SH,as above w/ 1mm organic layer & scat fish frags

pl ylsh brn SS,c-mg,v fnt bdg hzntl-low <,blk sh bed(2cm) 10cm fr top

dk ylsh brn SH w/ blk @ top & base,hd,blky

pl ylsh brn SS,vc-mg, parallel mud lam in lower mg rock, fltg pbls thru (mainly above scour & top), hzntl bdg thru

grysh grn-med gry SH,hd,blky,bcms mdy @ top

pl ylsh brn-grysh olive SS,fining up,cg-fg,fnt low < x-bds thru,
sm swell md clasts 30cm fr top, fg ss clasts @1706.45

pl ylsh brn-grysh olive SS,2 fining up sqnc,cg-fg bcmg v mdy twds top, fnt low < planar & low < x-bds,near hzntl @ top

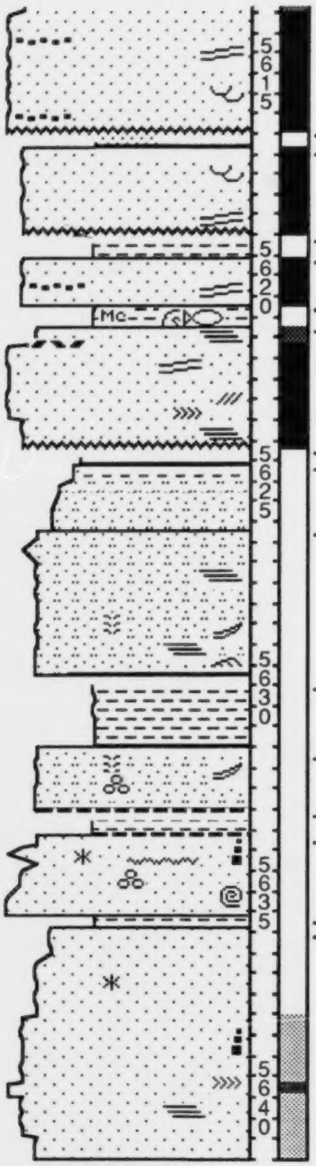
grysh grn SH,fg ss lenses incr to top, hd, mnr slicks

mixed d grn & d rd, abdnt lg slickensides ,hd, blky, scat crs grns

mod ylsh brn SS, c-fg, 2mnr scours @ top, blk sft sh (3cm)@1708.9 ,
few scat calc blebs

pl ylsh brn-olive fg-mg SS w/ blk & grn mud lam

pl ylsh brn SS, c-fg wl srtd bds (mm-cm) w/scat pbls, trough x-bdg &low < bdg, abdnt crs grns @ top



grysh grn SH,scat crs grns @ base

pl ylsh brn mg SS,w/few crs grn bds, scat bds swel md clst, v fnt low < & x-bdg

SH,as below but sftr

pl ylsh brn mg SS,w/few crs grn bds, scat bds swel md clst,
v fnt low < & x-bdg

d grn & d rd SH,mod hd,fsl,mnr slicks

pl ylsh brn SS, crs-fg, fnt hzntl-low-high < bdg,x-bdg ip, blk mud lam in fg ss,scat pbl,lg mud clast

grysh grn sh, abnt scat crs grns, hd blky

grysh brn vfg-slty SS w/drb wormy appear decr up ,bcm grysh grn @ top

grysh ol slty & dsky rd fg SS, wspy planar grn mud lam, w/ thn mg hzntl bds, dewtr str

dsky rd SH, hd, blky

grysh ol slty SS, wspy planar grn mud lam ,scat calc clasts & crs grns

dsky rd sh mott w/ d grn, hd blky sl fsl, scat crs grns

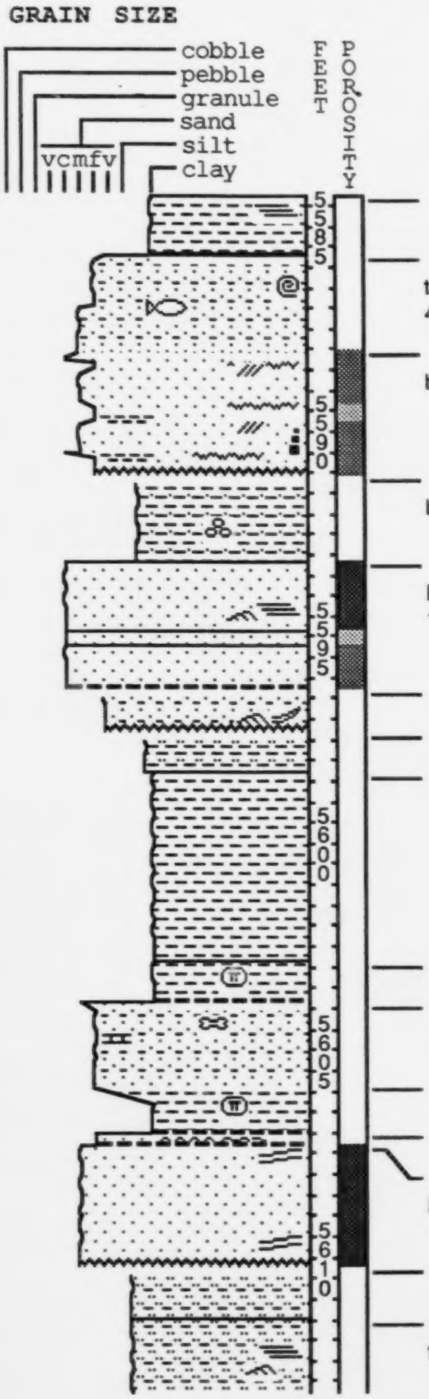
vgt grysh olive & dsky rd SS,2 fining up sqnc,scat limy clasts

dsky rd & dsky grn sh, mod hd blky, sl fsl ip

mottled dsky red & pl ol SS, fining up, thnly lam planar bdg @ base,5cm x-bdg @ 1719m, mass @ top

Amoco NGU Unit 294

2-11-80 -8w5



olive gry mdst

pl ylsh brn f- cg SS w/ grysh grn mud, bcmg mdyr twds top,no distinct bdg,thin blk lams @ top&base,scat pbls btm 40cm

pl ylsh brn SS,mg but f & crs bnds thru, 4 main units sep by minor scours,high < bdg, grn-blk mud lam @ base

grysh grn sdy SH, scat grs are f-crs some (4-6cm) bnds,scat calc clasts

pl ylsh brn SS,crs g,vp srtd,curr rip encased in hzntl lams,
10 cm zone of grysh grn md with abnt vfg-pbls

pl olive SS,grn md flasers, curr rip to hzntl top

pl grn slty SH,hd,blky,

d rd SH,hd,mod fsl,

grysh grn SH,hd,sl fsl,scales

-pl grn fg sdy SH,hzntl lam,mg-crs ss @ top,bones
-dk rdsh brn fg sdy SH,abdnt grn md drapes (1mm),bones

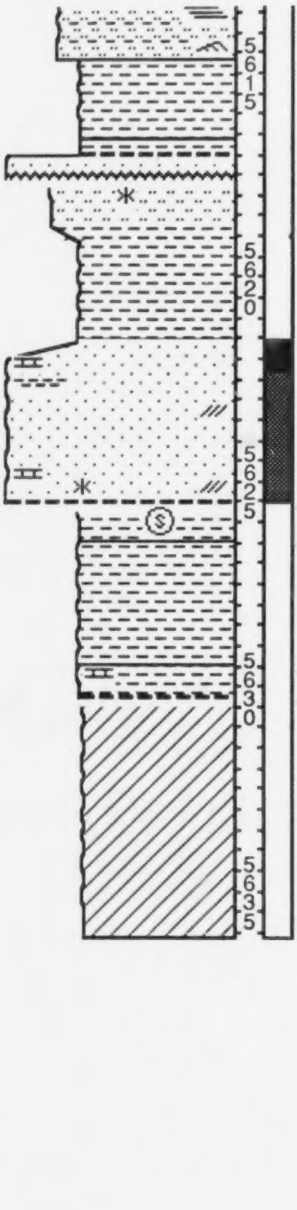
d grn SH,hd,wxy,micro-slick,scales,not calc*

ntrlam fg ss,mdy sh,pbl zone @ base

pl ylsh brn SS,mg,scat bds crs g,scat pbl thru,mass-fnt low < bdg thru

pl grn as below

drb mdst, pl grn slt lam,hd,blky,curr rip @base&30cm fr top,



d rd SH-pl grn SH@ base,grn lam,psbl burrows

f - cg pl ylsh brn SS, in1cm bds

pl grn SLST,mass,scat fg sand

dk rdsh brn sh - grysh grn @ base,hd,blky,abnt vert fract

pl ylsh brn SS,mg w/ crs bnds @ base,overall fining up,med-high< & x-bd,grnsh mdy lams @1713.7

mixed grsh grn & dsky rd SH,mod blky,fsl &wxy ip ,sparse micro-slicks

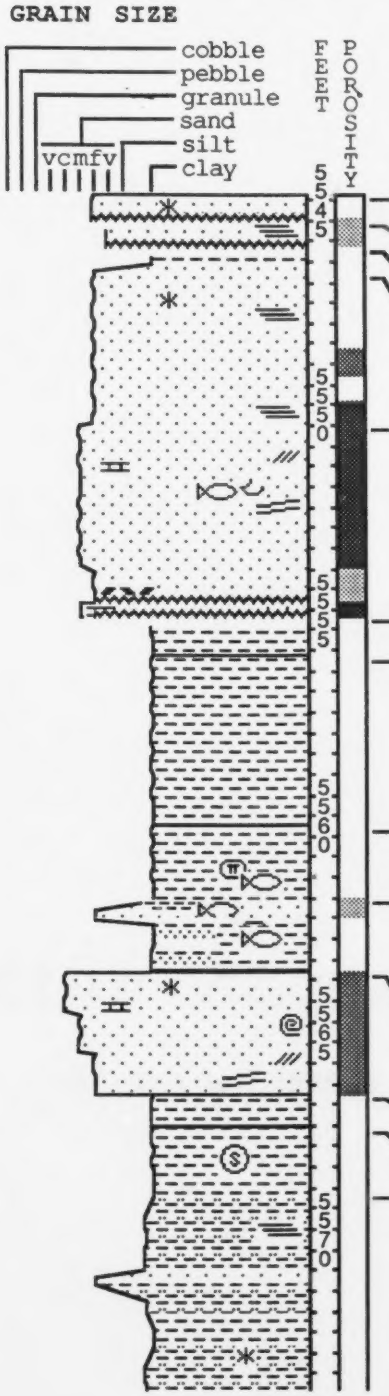
pl ylsh brn mdst,w/d grn & blk lams
btm 50 cm: intb dsky grn,dk rdsn brn, &pl ylsh brn SH

blk-dk brn SH,hd,v fsl

Top Muskeg

Amoco Unit 296 Nipisi

2-14-80-8w5 note: 1.5m lost core??



vcg pl ylsh brn SS

mod ylsh brn, fg, parallel lams

grysh grn SH, hd blky

pl olive - pl ylsh brn SS,overall fining up w/ variety of grain size thru, disc hzntl lam to mass ip

mg ss,crs & fg bds thru,crs is wl cmtd,high <,psbl trough bdg

grysh grn SH, hd, blky

dk rdsh brn SH,hd,sl fsl to blky @ top

dsky grn SH,mod hd,fsl,few scat lingula

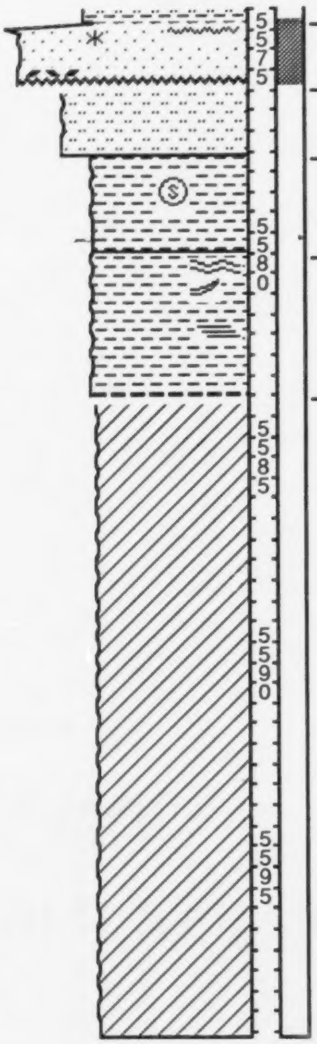
pl ylsh brn& pl olive fg SS w/dsky grn laminae,fish bones; blk SH, sft, fsl, abdnt scales; dsky grn & dsky rd SH w/5cm ntbd mg SS @ base & 5cm fg ntrbd SS @ top,bones @ top,lg slick

pl ylsh brn SS,crs up(but not evenly grad),low -high< planar bd, scat grn clay clasts thru top 3/4 &irr blk md clasts & lam,scat pbl

grysh grn SH,hd,blky

dsky rd SH,hd,blky,few lg slick

pl grn & dsky rd SLTY SH,hd,fsl @ cntr & 10cm f-m-crs g ss ntrbds, mass @ base,hzntl @ top



dk ylsh brn mg SS,1mnr scour @ top

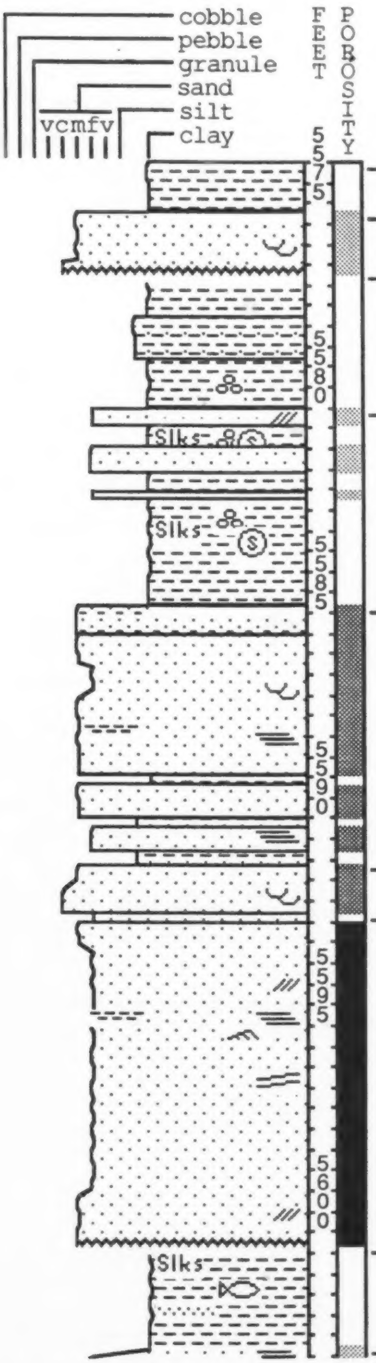
pale grn SLTST,massive,fltg med grns @ base

dsky rd SH,10cm dsky grn @ base,hd,mod fsl,few scat sm slicks

pl ylsh brn SH w/blk-dsky grn hzntl-wvy &wspy lam,mnr slick @ top

top muskeg

Pacific Nipisi
10-16-80-8w5



mod hrd part fsl sh, becmg hrd blky and gry to top

mg ss w/ psbl trough bdng hard to see, crsr cmtd bds

grysh grn sndy sh, decr in sndy up, mod scat limy clasts @ bot half of unit

intbd fg ss high > bdd ss w/ sft fsl sndy sh containing limy clasts, upper half grysh grn, lower half mixed grysh grn dusky rd. slks and microslks throu (looks like dirt or soil lp)

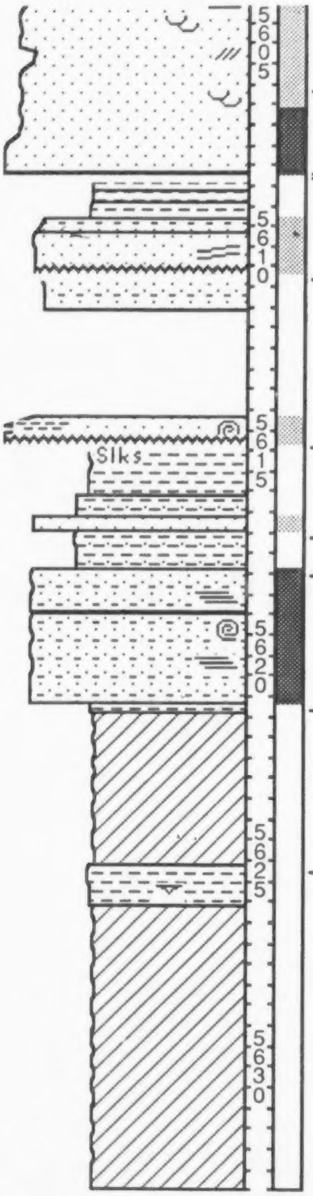
intb ss w/ sh, sh is grysh grn, mod hrd blky, mod fis - blky and caps fin up seq., ss is very variable but grnerally prly srtd, bdng hard to make out.

mg ss contains abnt scat cg-peb clasts, trough @ base

mainly fg ss w/ low-high > bdng, fair -well sorted throu except basal 20cm, thickest fg well sorted seen yet

mixed grysh grn drb sh, grn at sand contacts and mostly drb in mid, abnt large fish plates in cnter of unit, bot hrd blky , top soft fsl w/ slks

mg ss w/ few crsr cmtd bands, low-high > @ base, mid



trough, and upper fg planar horz bds

cg ss w/ crsr cmtd bands, abnt scat peb, trough throu

strange sharp contact for such a cg ss overlying sh

fin up seq, base fg ss low > bdng, mid grysh grn shly ss, upper sh is grysh grn @ both srid contacts and 8cm drb in mid

fin up seq. base 5cm cmtd cg ss, 5cm grysh grn hrd blky sh,fg ss horz bdng, upper mixed grysh grn drb shly ss with few scat limy clasts

mixed drb-pl grn sh, pl grn @ base and top 8cm mid part colour almost wormy in appear, mostly hrd blky, med blky w/ slks @ top

grysh grn very sndy sh, sim to below except more sh, some dewat struc& irreg drb patches

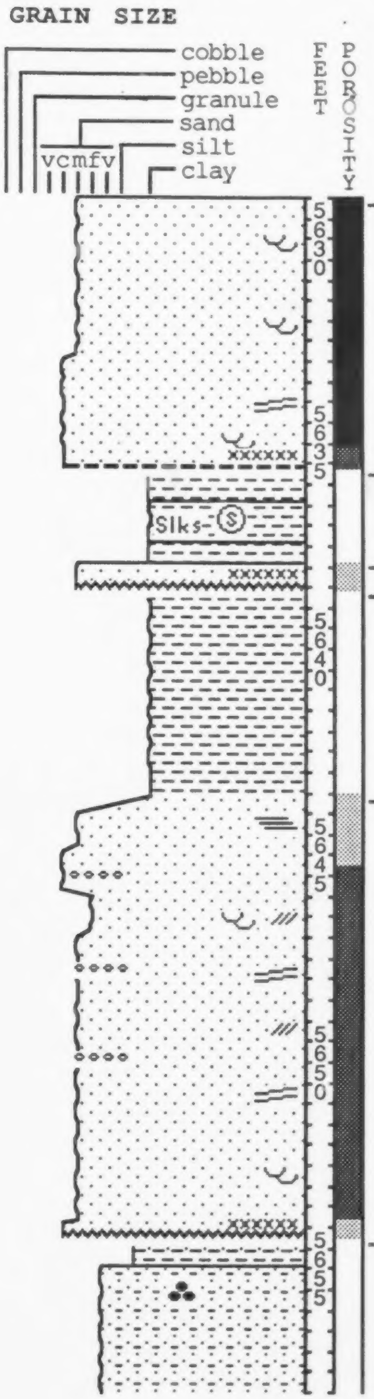
mixed pl grn ,grysh grn,drb fg shly ss-sltst, horz bdng, conv ip when shly

vgtd pl grn tan and thin dsky rd anhy sh, mostly tan

blk mod fsl sh psbl brac

Mobil NW Nipisi

12-18-80-8w5



mg ss w/ abnt crsr grs, bdng hard to see, mainly trough, grns subrounded & fair sorted parts

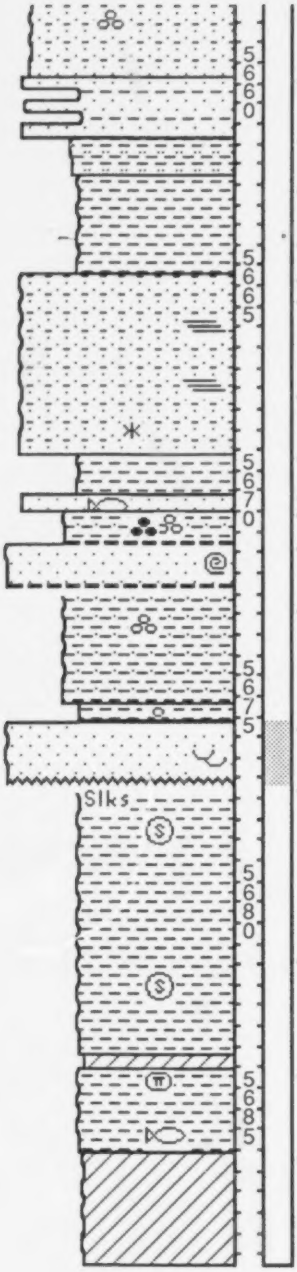
up- pl grn hrd blky sh, mid- mod hrd blky sh w/ slks & microslks, bot- pl grn mod hrd bly - fis ip sh w/ minor microslks

cmtd mg ss irreg bdng, scoured base, pebble zone3cm @ top but fins up

mixed drb-grysh grn med blky sh, mostly drb, slky through, thin 8cm sndy zone is more pl grn

mainly mg ss with very abnt crsr gr cmtd zones and scat snd grs, few peb zones, great variablity in gr size although they do fin up, sed struc incl trough, low & high > bdng, and horz bdng at top of unit. core is broke up into many small peices for core analysis

up 15cm grysh grn sndy sh w/ 1 limy clast, 45cm of large irreg shaped limy areas sep by disc sh lams, limy area very dense, rest is grysh grn shly ss fg w/ few scat limy area, and pos horz-wavy bdng.



intbd snd sh & cg ss, gs and thick of ss bds decr up from cg -fg

pl grn slty sh w/ faint horz -wavy bdng and water escape features

drb mod blky sh, minor grn areas

irreg patched gry anhy 90% w/ drb sh, hrd blky

pl grn mas shly ss w/ few gry patches

gry shly ss very calc, many approx horz-wavy mud lams through, upper 20cm is mixed pl grn, gry, drb in col

pl grn fg shly ss, mas @ base and approx horz @ top.

drb mod hrd blky sh, grysh grn wormy ip, sndy @ base

fg ss completely cmtd, bdd hard to make out, irreg at best.

grysh grnsh sndy sh - sh, dense limy areas @ base decr to top, w/in dense limy areas its actually smaller ones packed together sep by styl

mg ss, cmptly cmtd in irreg patches, inferring conv bddng, bddng hard to disc

drb sndy sh-shly ss, scat limy clasts throu, psbl root infilled w/ limy material, basal 20cm and upper 10cm is more pl grn

mg ss w/ abnt scat crsr grns, psbl trough, cmtd more at base

top 20 cm pl grn hrd blky sh, 56 cm of med blky drb sh w/ scat mixed brec grn areas - scat microslks & slks through, 28cm mainly dsky rd med blky sh mixed w/ minor grysh grn brec appear, slks throu, base 15cm is grysh grn mod fis waxy sh w/ scat fish scales

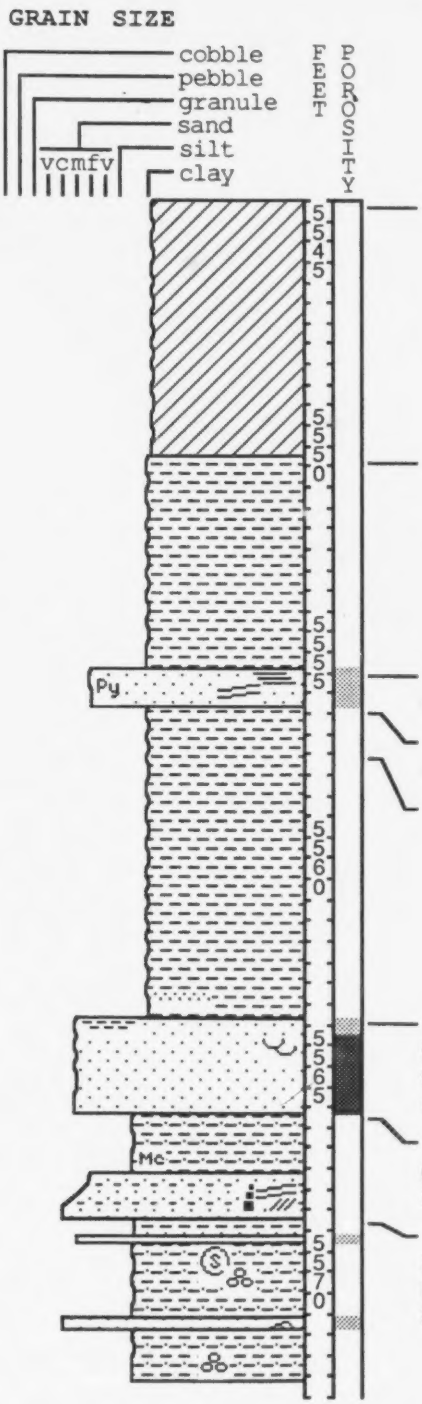
dsky rd med hrd blky , upper 15cm very fis waxy dsky rd sh w/ microslks, bot 15 cm is grysh grn wxy mod fsl sh

top 3cm blk fsl sh, 18cm mod fsl wxy ip grysh grn sh w/ scat fish scales, 18cm dsky grn - gry hrd blky sh, 6cm pl grn fis sh w/ abnt fish plates

tan anhy sh, vgtd ip (dsky rd, dsky grn, tan , blk), horz bdd

Atlantic Muskwa

10-32-80-8w5



anhy

drk gry hrd blky sh

f-mg ss bed 26cm. contains low > and horz bdng. pos crs up

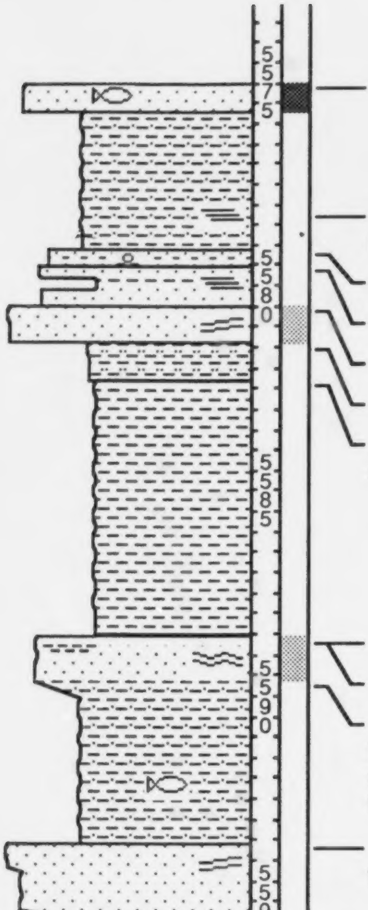
hard blky gry sh, 13cm from base there is a 3cm cg-peb ss bed

anhy clasts 3cm x 2cm

avg mg ss, gr size changes rapidly into many small 3cm fin up seq with vcg @ base to fine gr at top, one long 17cm fracture goes through the ss and is filled with grysh grn sh. upper 18cm is a intbd fg ss with the overlying grysh grn sh.

fin up seq. from cg ss @ base w/ few mud clasts and grysh grn sh beds up to a sandy sh containing all gr sizes and is mic

Thick unit of sandy shale vgtd pl grn & drb, three thin 8-13cm m-cg ss beds which have faint low angle to horz bedding. scat limy clasts throu but also conc more in a 30cm zone in the center of this unit, few scat micro slks



can not make out bdng, psbl low angle to horz

very thinnly bdd grysh grn fg ss w/ drb sh ss beds(1mm-.5cm) sh(.5mm-1mm)

grysh grn sndy sh crumbly to touch, few limy clasts

intb mg ss w/ 2-3mm grysh grn sh, horz bdng

cg ss w/ low angle bdng, crsr bands cmtd

pl grn hrd blky slty sh

drb hrd blky sh, brec look throu, 3 small 1x.5cm anhy clasts found in upper 40cm

fg ss w/ few 1cm grysh grn sh intbs, bdng is irreg

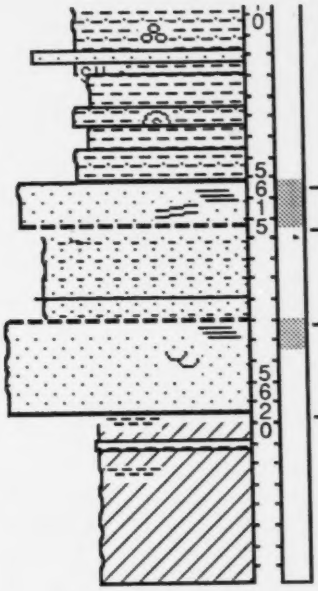
mixed drb-grysh grn sndy sh, w/ abnt fish plates in bot half of unit bot15cm is intbd mg ss.25-1cm w/ grysh grn sh1cm. abnt fish plates upper part of unit is mainly drb hrd blky sndy sh some parts being very sandy

f-cg ss, overall fin crs up, bot half f-mg shly ss crumbly to touch, upper half cmtd cg-peb ss w/ few mud clasts

mixed grysh grn w/ (less drb)sndy sh, very sndy ip and fin up when sndy, mod amt of limy clasts w/ more in the upper half of this unit

cg-fg ss, overall fin up and small fin up seq,
bot is cmtd, low angle, is underlain by 2cm of pl grn sh
mid is crs -fg ss low -horz bdng, crsr bands cmtd
upper is med-fg ss w/ more shly intbs and horz bndg

mixed drb-grysh grn sndy sh, mostly drb-dr ip, few scat limy clasts, slks throu and v abnt ip, one thin 11cm mg ss bed with no discernable bdng



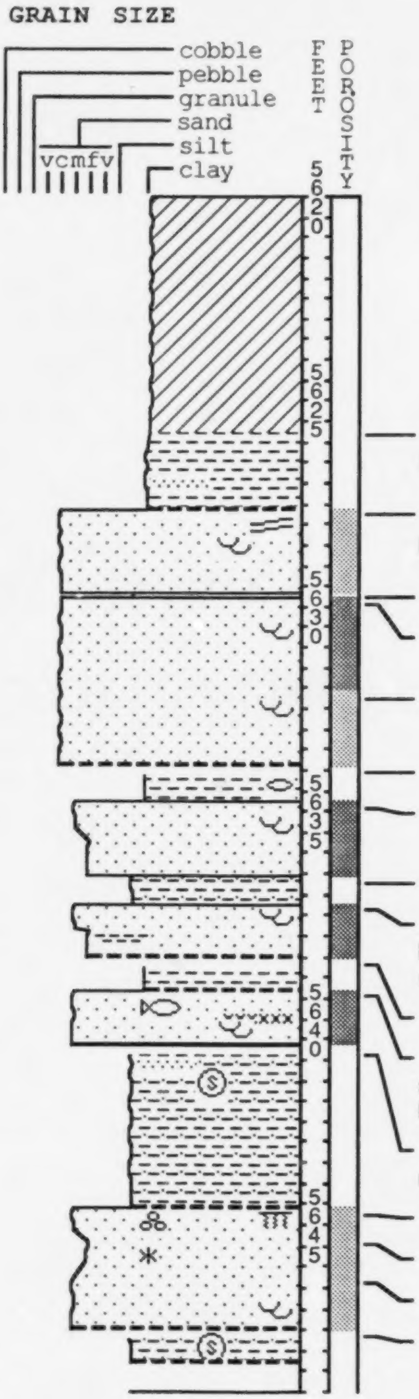
mg-fg ss w/ low > bdng to planar @ top, cmtd

muddy ss, irreg mixed in col (drb & grysh grn), ss is m-cg

cg ss ol in col, trough @ base w/ few mud clasts & more horz to top, very well cmtd @ base

tan-vgtd anhy mudstone w/ few pl grn and drb thin 1cm shale intbs

Mobil Utik Nipisi
12-21-80-9w5 Depth's may be out



dsky grn hrd blky sh, bot 5in is sl fsl and sndy, upper 7 in is intb w/ anhy

dyb m-cg ss mostly trough, some low> - horz @ top, partially cmtd

dsky grn sndy sh, hrd blky

dyb m-cg ss, trough bdng throu

plb m-cg ss,trough bdng, almost completely cmtd w/ anhy

ol gry hrd blky sh, lrg anhy noduals2x2cm,

dyb f-mg ss, trough bdng,

dsky grn sndy sh

pyb f-cg ss, disc sh lam bot half & very well cmtd, trough bdng,
upper half not shly, trough & less cmtd

dsky rd sndy sh, hrd blky

pyb cg ss, bone, psbl trough, irreg bdng not conv looks slumpded @ top, anhy clasts 1x2cm, cmtd ip, mudy @ base

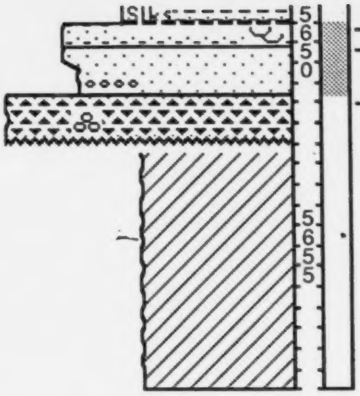
mixed dsky rd, grysh grn, sndy sh, hrd blky, slks, microslks

m-cg ss w/ abnt scat limy clasts, mdy ip, pos low > bdng

grysh grn mg shly ss, limy clasts @ top, mas

grysh grn mdy ss, trough, almost thinly bdd

dsky red sndy sh, slks,microslks, mod blky

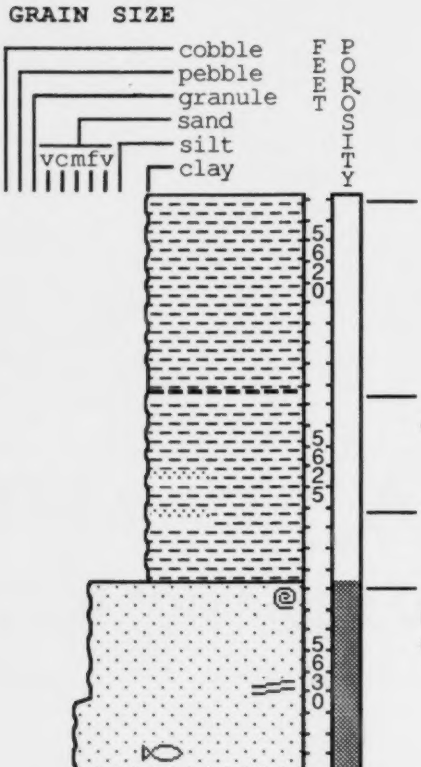


pl grn mdy ss, all grain sizes, trough

peb cong at base, fin up into mg ss w/ abnt scat peb, trough

Breciated zone, incl pebs, sand, and abnt limy clasts

4-24-80-9w5



dk ylsh brn anhy sh thinly lamd through

dsky grn sh hd fis, mas in appear, slty @ bot 10cm near contact

fg-crs gr sndy zone 5cm thick

pl ylsh brn - drk ylsh brn crs-fg ss, overall fining up but not gradational, dewatering struc in fg ss givng conv appear

dsky grn sh, med, fis

pl ylsh brn crs gr - peb ss, well cemented, scat mud clasts (1cm)

grysh grn shly mg ss, mas,slicks

pl ol -grysh ol fg ss, w/ scat wvy discont horz mud lams through, sm lmy blebs scat in upper 14 cm

pl ylsh brn fg ss, faint horz lam

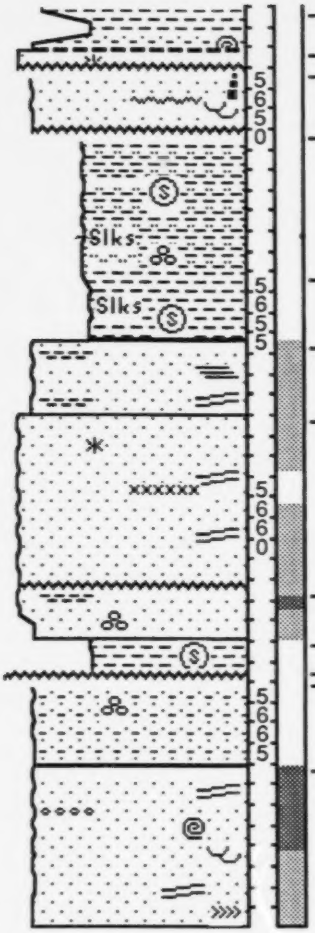
pl grn SLTST, mass, blky

pl ol cg SS, well cmtd, grds into dsky rd slty SH above

drb & pl ol & grysh grn SH, bot 20cm mainly limy blebs, brecc above, slty @ top w/2 (5cm)lam zones,sm fract thru lgr @ base

grysh grn slty SH,grdg up from below

pl ylsh brn-pl ol ss, abnt sm grysh grn mud clasts & scat



crs grns

drb SH, hd, fsl, grdg down to pl olive & grysh grn shly SS, churned w/ hzntl lam @ btm

pl ylsh brn mg SS, abnt crs grns @ base,wl cmtd, abnt md clsts(2-15mm)

pl olive fg SS,3 fining up sqnces w/mg-crs lags, trough bdg, thn hzntl sh lam top 5cm

drb slty SH, grysh grn @ top & btm 15-20cm, sltyr @ base, shlyr @ cntr, scat slick & micro-slick ,sm lmy blebs @ base

dsk rd SH, hd, fsl, abdt slicks & few micro-slicks

pl ylsh brn-drb-grysh grn fg SS, sh lam @ top & btm (hzntl-low<), chaotic bdg btwn lam

pl ylsh brn mg SS, low< bdg thru, bcmg mass @ top, scat grn shale clsts @ top

pl ylsh brn SS, cmtd fg @ base mg @ top,sm (10x3mm) lmy blebs w/stylo, scat crs grns & bcmg mdy @ top

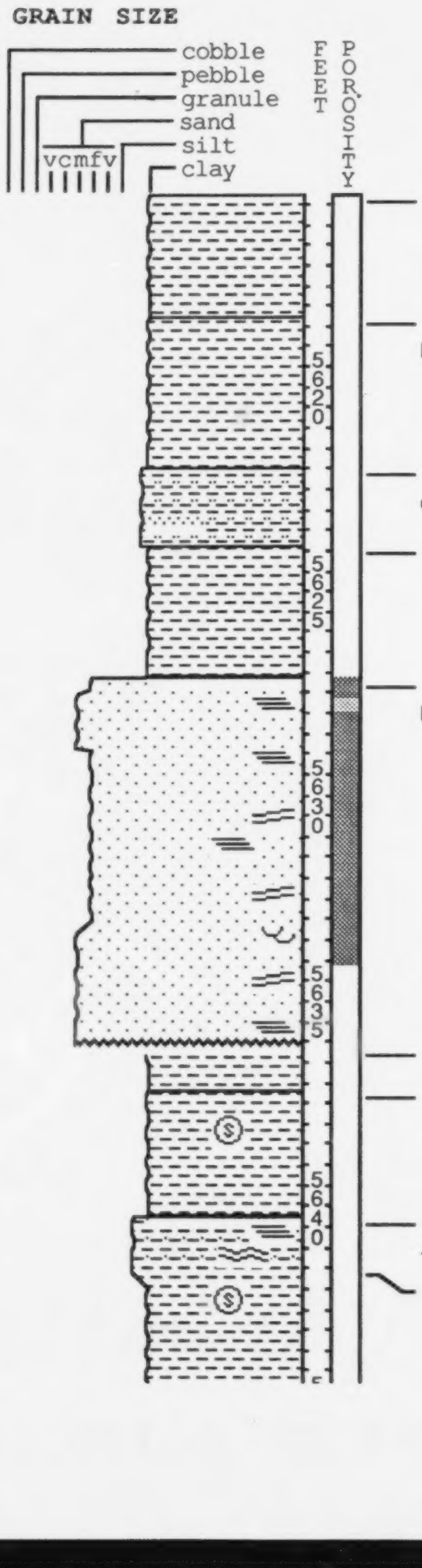
grysh grn &dsky rd SH,limy blebs & brec app @ base, abnt slks

pl ylsh brn-grn crs mdy SS,mass

grysh grn &d rd shly fg SS,limy sltst blebs & brec app @ base

pl-dk ylsh brn fg SS, abdt mg bds @ topgd srt @ base bcmg pr to top

Arco IOE Nipisi
4-25-80-9w5



dyb thinly lam anhy sh

dsky grn sh mod fls, one sndy sh bed 2cm thk,\7cm from base.

slty grsh grn sh w/ scat sand gr (f-crs) throught but more conc at bot, hd fis, thin lam at base

dsky grn sh hd very fis in parts

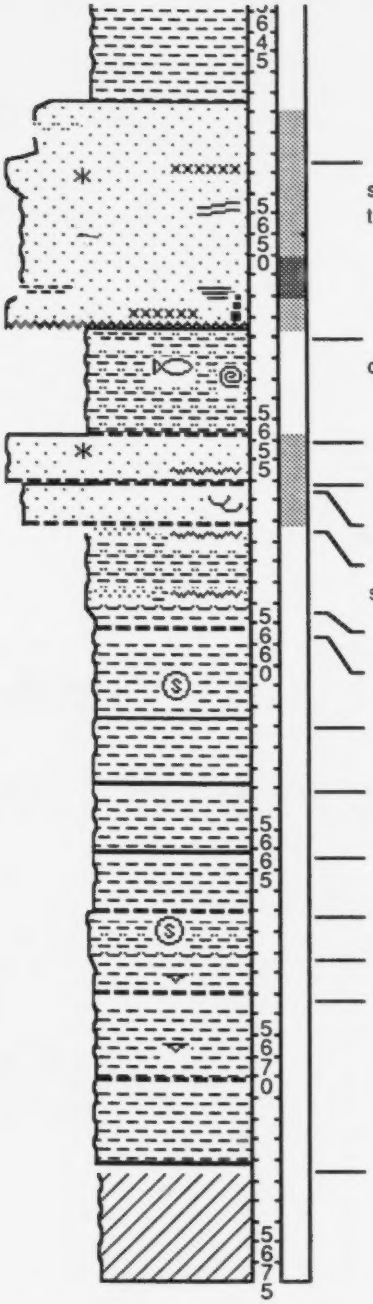
pl ol - pyb, m-fg ss, abnt scat crs gr and peb. some bimodal beds, mainly low > bdg some psbl trough

dsky grn sh, sft, slightly fsl

drb sh, mod fsl, minor slks

pl grn sndy sh, sand is mostly vfg some mg, thin lam horz - disc wavy

dsky rd sh hd fis, slty at base, slks through



dyb ss fg-crs gr, overall fining up not gradational, crs gr ss cmtd, bcmg slty in upper 30cm w/ scat crs gr, hor - low > throu

drb-grsh grn slty sh mot appear,dewat struc throug, capped by 3cm grsh grn sh hd fsl

pl grn crs ss, mass

drb -grsh grn sh, slick across whole core, hd

dyb,med gr ss, faint trough x-beds, scat crs grns

grsh grn, dsky rd, pl ylsh brn, slty sh, few minor scour surfaces

pl grn sh w/ abt any sh, brecciated

drb @ base - drb @top, med very fsl, mirco slicks

intbd dsky grn, drb, pl ylsh brn, conv @ base -//at top

blk sh, very sft and fis

pl ylsh brn anhy SH, mdy ip ,w/ blk lams

dsky rd, slty sh, hd, slks, mot appear w/grsh gr

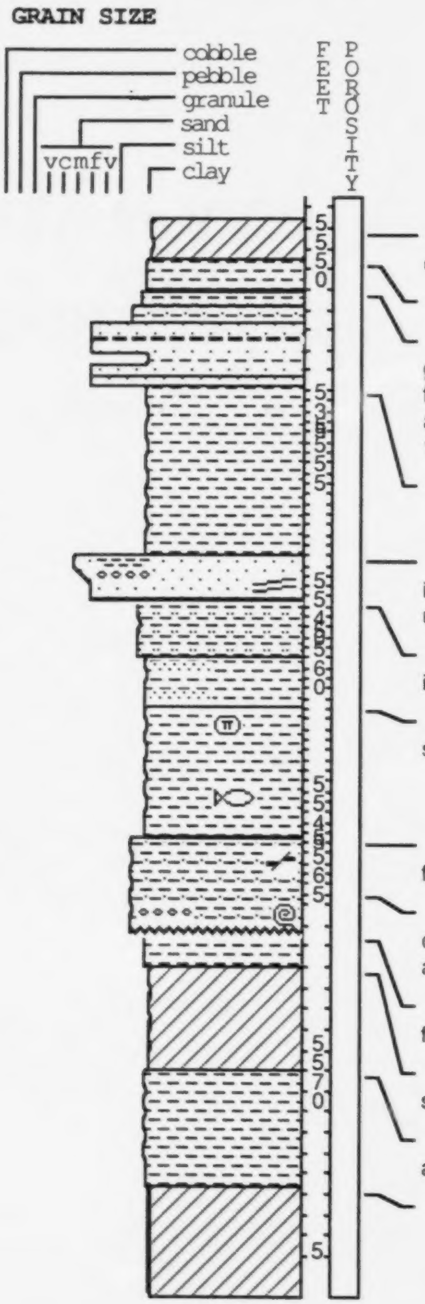
dsky grn - blk sh, med fis, minor bracs

pl ylsh brn anhy SH, mdy ip , w/d grn & blk lams

Top Muskeg

Pan Am H-2 Nipisi

12-32-80-9w5



anhy most gry - tan horz bdd, not drk brn limy anhy sh like other cores

grysh grn - gry hrd blky sh

base 7cm fg ss w/ low > bdng, 20 cm biot intbd fg ss w/ grygh grn sh (contains low > - horz bdng,climb rip, mud flasers, conv @ top,), 19cm fg ss w/ few mud lams -low angle bdng, 5cm horz lamd fg ss w/ grysh grn mud, upper 15cm grysh grn soft sh, cp 1-2 top snd 3bot snd

grysh grn - gry hrd blky sh

ss unit cp4 is lower fg ss w/ low angle bdng, upper 15cm isf-mg ss matrix w/ abnt scat peb up to 1.5x1.5cm. uppermost 3cm is horz intbdd grysh grn mud w/ fg ss

grysh grn sh, 50 % sndy-slty, sndy pts are horz bdd, sh is sft-mod fsl

grysh grn mod-sft fsl sh, one fish plate, and a few scales slightly mic throu,

upper 25 cm is lams fg ss-sltst w/ grysh grn sh, normal faulted

conv- brec sndy-pebly sh w/ clasts of anhy and calc mud one clasts of feld approx 2x2cm, sh is grysh grn, high angle bdng @ top-slumped, decr in gr size up.

intbd anhy sh, sh dsky grn fsl, curved wavy bds @ top, following scour from snd above.

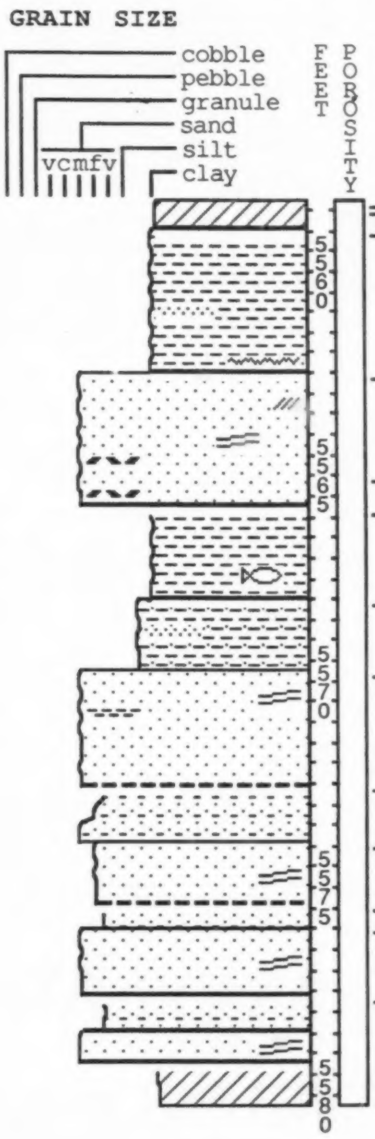
low angle bdd anhy - conv @ top, few thin 1cm dsky grn sh bds

mas grysh grn - gry hrd blky sh pos w/ scat anhy, pos all anhy

horz bdd anhy mas ip and shly ip

Amoco Et Al Nipisi

5-34-80-9w5



Is actually 10 boxes but I used only boxes containing Wt Mtn. And started the depths from the anhy sh contact

drk brn horz lamd anhy sh

dsky grn soft fsl sh, upper13cm is hrd blky and like a transition zone, sh is sndy ip w/in bot half of unit(flaser bdng), -a 2cm cg ss bed is present 4cm from bot of unit, this ss is crsr gr then the upper part of the underlying ss

mg ss w/ high > bdng @ top and low > throu rest, small .5x1cm mud clasts scat throu.

intbd ss&sh for bot 15cm

dsky grn - gry hrd blky sh, some fish plates in centre of the unit

grysh grn mod sndy sh, very soft fsl ip

mg ss, olive, low > bdng but hard to see in lower half, few mud lams in center of unit

f-mg shly ss, shly incr up, few low angle bds present

fg ss, well srtd, faint low > bdng, brn in col (dif then upper sand)

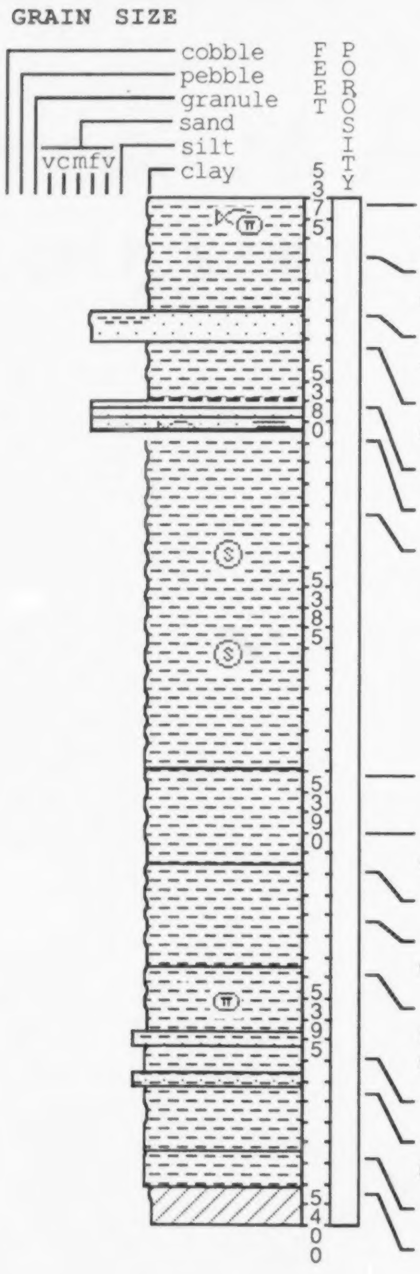
pl grn shly fg ss, calc cmt @ base

pl ylsh brn mg ss, bdng hard to see. psbl lo > , snd grns rndd-subrndd

top of fin up seq. mg ss low > bdng w/ pyr and subrounded grns up to pl grn shly ss. some pyr in lower ss,

Pan Am G-1 Nipisi

13-7-81-7w5



grysh grn mod fsl, med-waxy sh, very abnt fish plates, & scales

dsky grn - gry hrd blky sh - sltst, base 5cm has abnt scales and mod fsl

fg ss approx hzntl wavy bdng, mud flasers, ss content and gr decr up,

base 17cm is mod fsl dsky grn sh, upper part is pl grn hrd blky sltstn

shly ss, fish plate at base of unit

grysh grn hrd blky sh, scat small drb specs ip,

drb -dsky rd hrd blky sh, scat slks (minor in number)

grysh grn - pl grn hrd blky sh

gradational contact zone for 30cm, mainly grysh grn some drb

mottled drb - dsky rd mod fsl sh

drb hrd blky sh, gradational contact from below mottled for17cm

med fis grysh grn sh w/ few drb spots, hrdr in sndy areas, large 5x3cm anhy clast in center of unit, sndy spots are fg ss, scat minor fish scales

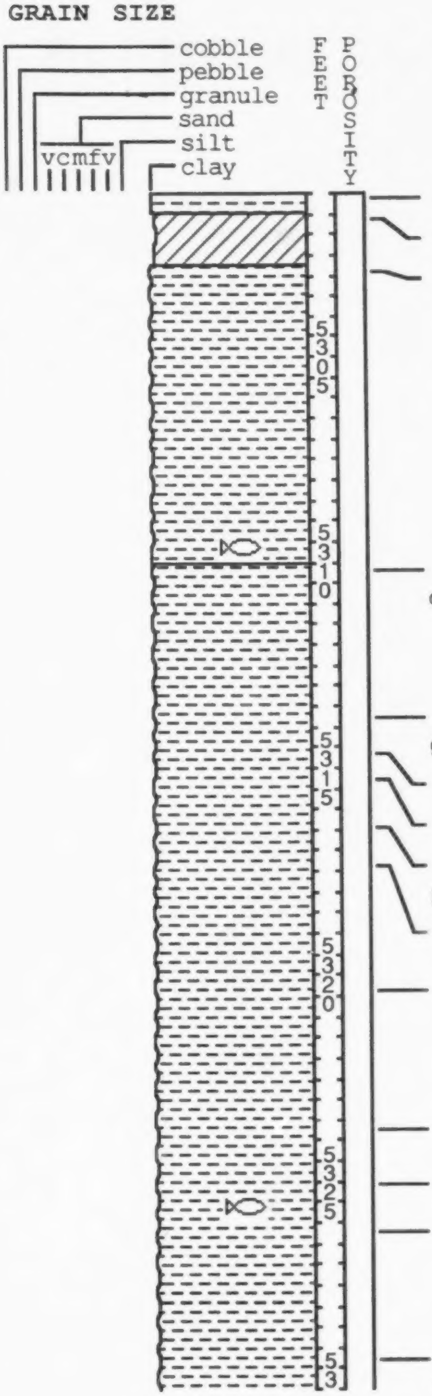
anhy clast 5x3 cm

mixed & mot drb & grysh grn hrd blky sh, grnish upper 5cm in contact with sndy unit

dsky grn - gry hrd blky sh

tan anhy w/ horz bdd gry anhy bds

Pacific et al Nipisi
10-20-81-7w5



med blky grysh grn sh

intbdd tan anhy w/ thin grysh grn sh bds .5cm

grysh grn mod hrd - fsl on edges, fish plate at base of unit

mixed drb-grysh grn mod-hrd fsl ip sh, few sm 1x.5 anhy clasts in upper 10cm of unit

upper 25cm mod fsl grysh grn sh, lower 25cm mixed grysh grn, drb sh at gradational contact

one anhy clast 1x.5cm

drb hrd blky sh

pl grn hrd blky sh w/ 1 drb patch, few sm anhy clasts present 2x1cm

drb-dsky rd hrd blky sh, scat pl grn patches

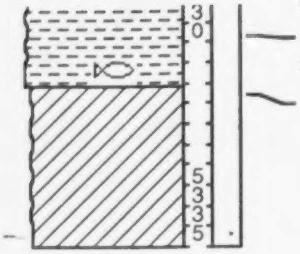
anhy clast 1x2cm

brec drb hrd blky sh

pl grn hrd blky sh w/ fish plates conc @ base

drb hrd blky sh

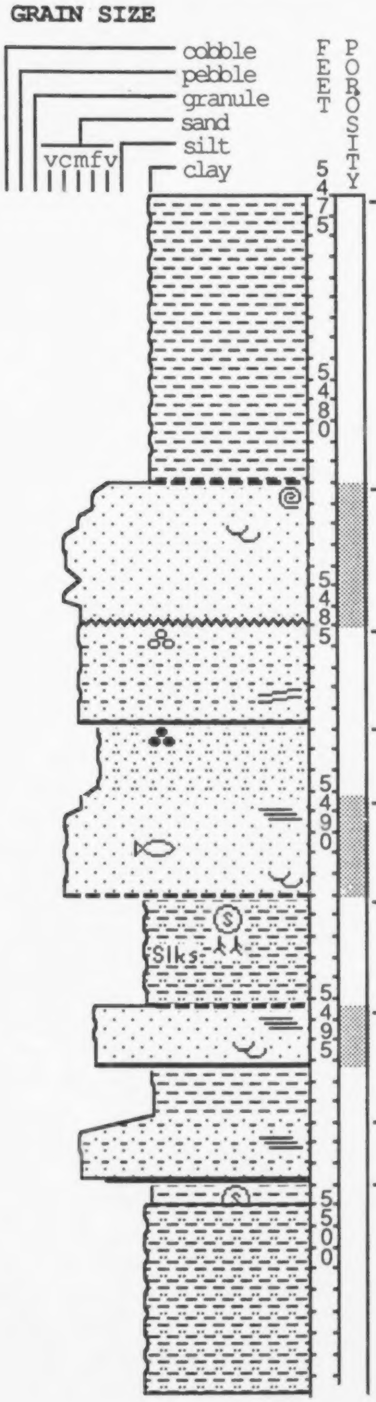
7cm of pl grn hrd blky sh, irreg wavy upper contact sharp lower contact



bot pl grn hrd blky sh w/ plates, grad up to drb brec in appear hrd blky sh

tan anhy, upper 24cm is brec w/ pl grn sh

Atlantic IOE Nipisi
10-5-81-8w5



dsky grn-gry hrd blky sh

f-crs gr ss, fin up, trough @base and upper 9in distur, completely cmtd

pl grn shly mg ss, scat limy clasts @top

dense limy clasts in a slt-mg ss in upper 8cm, grading down into a intbd ss & slt horz bdd unit.

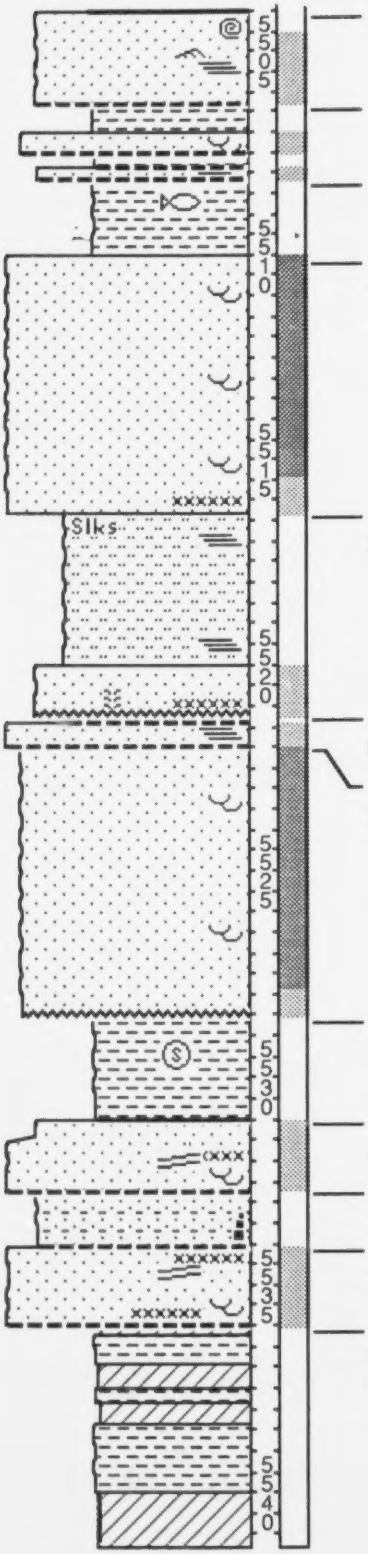
cmtd dyb-pl grn cg ss, trough @base bcmg horz @top, fish bone

mot appear drb-grysh grn hrd blky sh, pos rooting, abnt slks&microslks

pl grn fg ss mudy ip, trough

pyb-pl grn f-crs g ss horz bdd,partly intb w/pl grn sh, few mud clasts

upper 9cm pl grn hrd wxy sh, below is mixed mostly drb w/ less pl grn giving brec appear, minor amts of microslks



mixed drb-pl grn fg ss, both horz bdd & cur rip(climbing ip)

pl grn hrd wxy sh

pl grn hrd wxy sh, fish plates

pl ylsh brn cg ss w/ abnt peb, one 2x1cm, cmtd @base 1ft,

mixed grysh grn-drb slts, slks in upper 2ft, faint horz bdng ip,

pl grn med fsl shly slt,
below is intb cg ss 1-2cm w/grysh grn mud .5cm, horz bdd.

pl-drk ylsh brn mg ss, cmtd crsr bds @base, mainly trough bdng.

drb hrd blky sh, few micro slks.

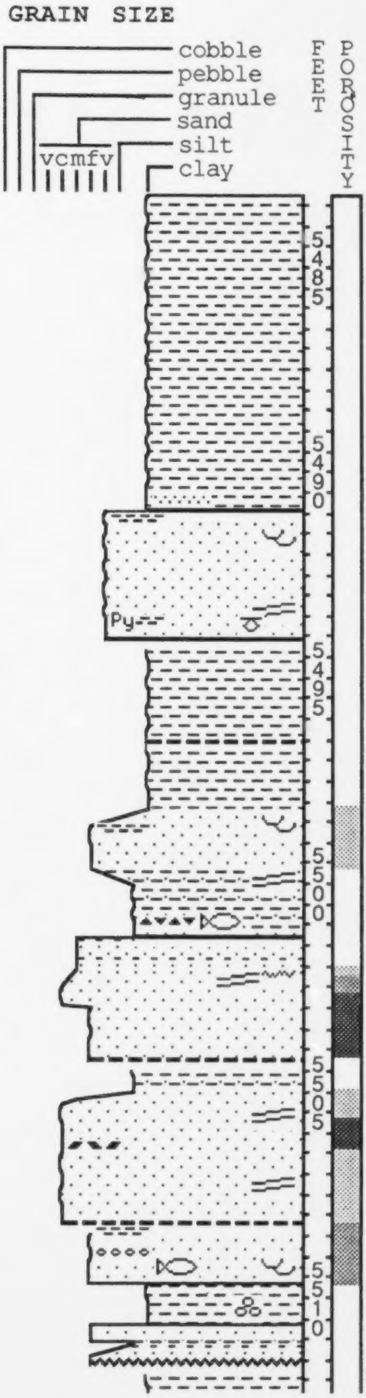
pl grn f-cg ss, mainly cg w/ abnt feldspar clasts, mostly cemented, fin up, mainly low angle bdng.

shly ss, mainly f-mg, grysh grn @ base, drb @top

pl-drk ylsh brn mg ss, mostly cemtd, trough @ base, faint low > @top

intb pl ylsh brn - tan anhy w/ dsky rd - grysh grn hrd blky sh. Some of the anhy cont micro frac that are dsky rd. Lowest sh is blk hrd fis. no fos found

ARCO IOE NIPISI
12-5-81-8w5



gry SH, grnsh twds bot, hd,blky-sl fsl

pl ol vfg SS, scat mic lams, shly bds@top&base, sets of trough&high<

grysh grn SH, mod hd-sl fsl

blky SH,drb-dsky grn @ base,sftr@ fsl base

pl ylsh brn fg SS, scat thn dis sh lam @ base

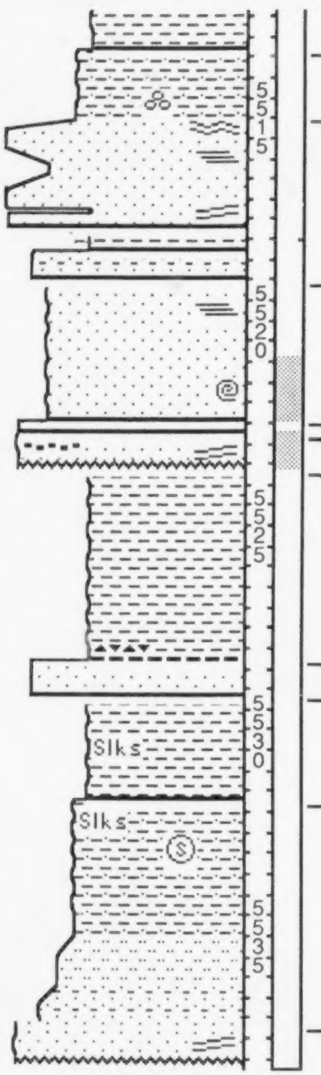
drb - grysh grn,pl ol sdy SH,more ss @ cntr & top,brecc @ bot, unkn fos @ base

pl ylsh brn c-fg ss, several fin up sqncs, trough @ base&low<thru

pl ylsh brn fg SS, good srtg, fish armour frag @ base, BEACH?

mixed dsky rd & grysh grn SH, grn @ top, mod hd blky, scat limy blebs bot 8cm

intbd SS/SH(1cm), sh bds consist of thn hzntl-wavy lam;



shly SS @ base, fg w/scat crs grn lag low<, scat crs grns thru

drb SH,sft sl fsl, abdt grn micro-fract/des crks?

lam grysh grn,dsky rd sdy SH, sim to sh lam below,1cm curr rip@base, bcmg sdyr to top, scat sm limy blebs palsol?

intbd vgt SS/SH, crs(bimodal) bds (1-10cm),

pl ylsh brn bcmg grysh rd @ base,abdnt scat m-crs grn thru

ylsh brn bcmg grysh rd @ base, abdnt scat m-crs grn thru

pl ylsh brn mg SS, welll cmtd, low-hgh <, scat md clsts

drb SH,as below,grysh grn @ top 5cm,brecc app &sdy @ base,roots?

drb, grysh grn SH, intbd w/ pl ylsh brn fg SS

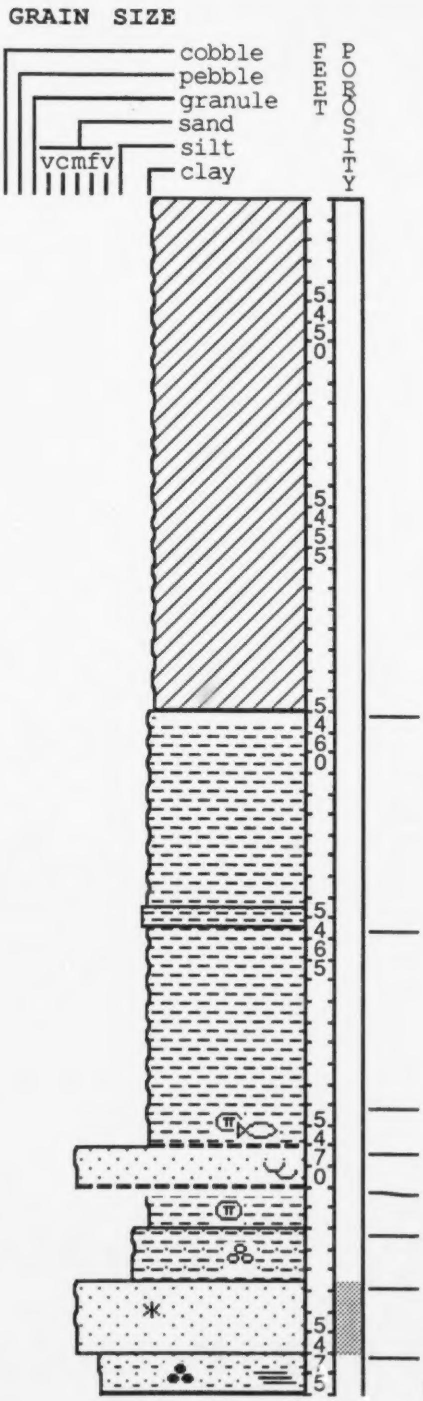
drb SH, hd, blky, abnt slicks

grysh grn & drb sndy SH,SLTST,SS, abnt slicks

pl ylsh brn-pl ol mg SS, v cmtd, scoured contact? @ base

Atlantic Muskwa

4-10-81-8w5



dsky grn - gry mod fsl sh

dsky grn - gry hrd blky sh

grysh grn v fsl sh w/ abnt fish scales and few plates

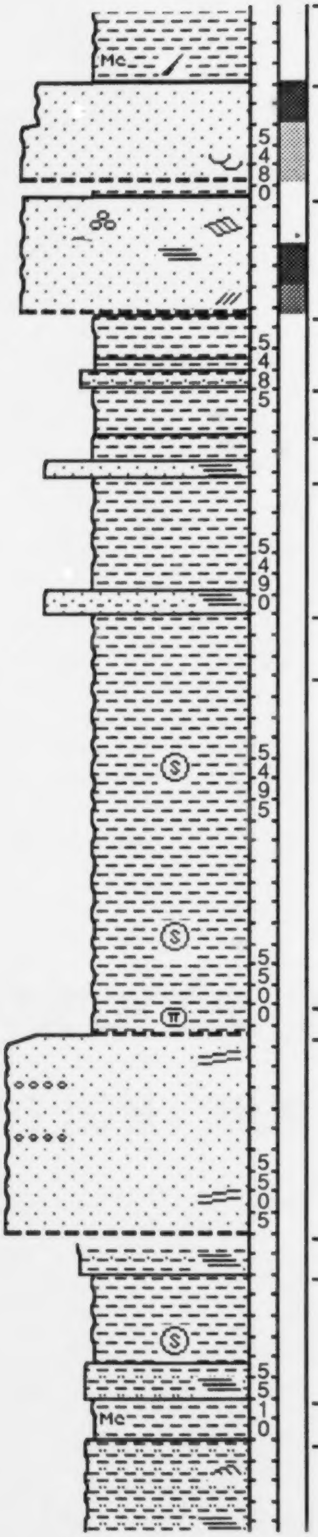
mg ss w/ pos trough xbdng, sim in appear to ss below

grysh grn mod fsl sh w/ scat fish scales, waxy

grysh grn sndy sh w/ few limy clasts

pl grn mg shly ss, mass in appear

grysh grn shly sltst w/ abnt limy clasts almost dense., many of the limy clasts are orientated vertically while bdng



is horz

mixed drb-grysh grn mod blky sh, mic ip

fin up seq, mg trough xbdng @ base to fg ss @ top . can not see bdng in upper part of the unit.

fin up cycle mg high > xbds @ base to fg starved climbing rip - horz @ top, flaser bdng, few small <.5cm scat limy clasts w/ in fg ss

intb pl grn-drb hrd blky sh w/ a few sandy sh beds that are always pl grn. some of the pl grn shales have a strange appear

drb hrd blky sh

pl grn hrd blky sh

drb hrd blky sh

pl grn hrd blky sh

from here to next comment is all broken up rubble. mainly drb hrd blky shw/ scat grysh grn spots, few microslks in drb sh

grysh grn md fsl sh, w/ scat fish scales

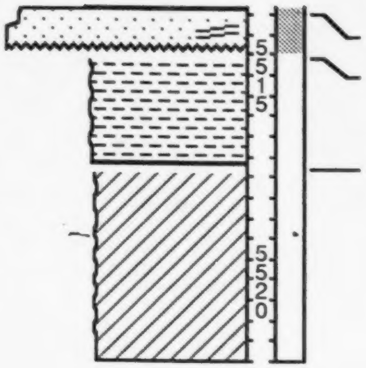
cg ss w/ scat pbl zones (pebs up to 2x1cm avg1x1), low > bdng throu, upper 5cm is a fg shly ss w/ a few mud clasts

pl grn hrd blky sndy sh, sub horz lams

vgtd pl grn-drb sh sndy ip, worm like appear, scat microslks

vgtd pl grn drb sh, mic on bedding planes ,sub horz lams

base 14cm pl grn intb ss sh sim to ph126 but beds not as well defined upper part is drb slty sh w/ horz lams @ base to cur rip @ top, all is somewhat deformed by water escape features



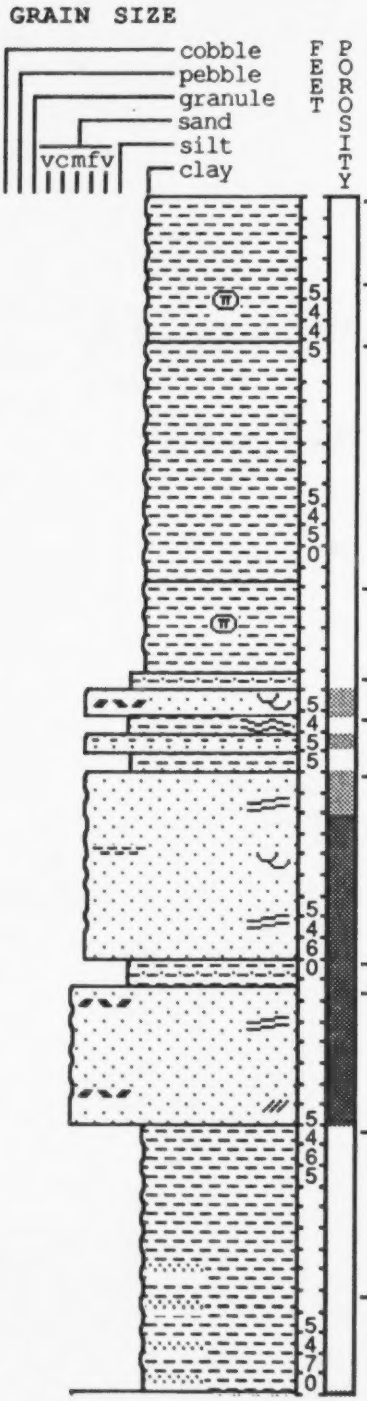
cg-mg ss fin up, abnt fldspar clasts, low angle xbdng

drb hrd blky sh, upper contact w/ ss is sndy sh for 6cm

tan anhy sh

Atlantic Muskwa

4-15-81-8w5 Slabbed



grysh grn - gry hrd blky sh.

grysh grn very fsl sh. psbl 1 fish scale

grysh grn - gry hrd blky sh

grysh grn mod fis -very fsl sh w/ abnt sm fish scales

fin up, fg ss w/ abnt sm 1cm mg bds, trough throu, and scat mud clasts up to 2x2cm, sndy sh has aprox horz wavy bdng

grysh grn shly snd - sndy sh, approx horz wavy bdng

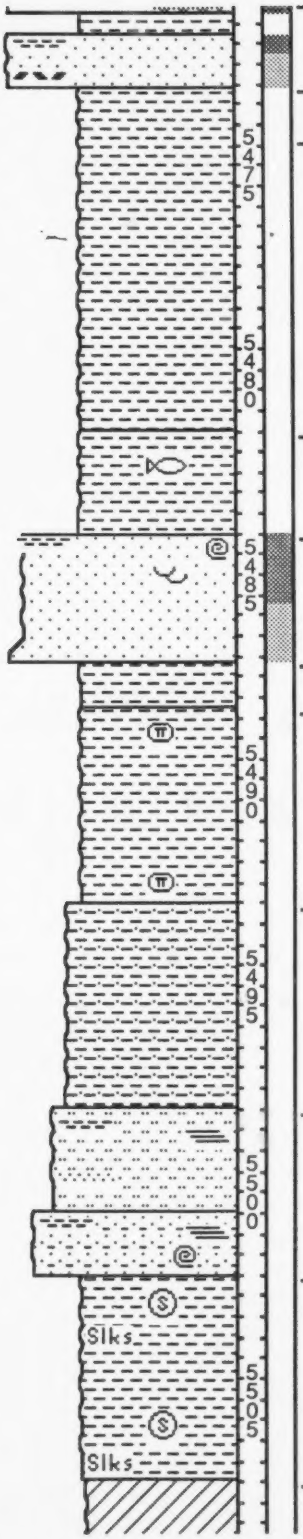
fin up seq. all mainly fg ss but scat m-cg clasts decr up, mainly low angle xbdng throu, but one15cm trough bdng zone is btwn two thin 3cm grysh grn sh bds

grysh grn sndy sh to sh @ top,

mg poorly sorted ss w/ scat mud clasts throu, high > xbdng @ base to low > xbdng @ top, bdng conv w/in zone of dense mud clasts

grysh grn hrd blky sh, sndy @ bnase decr up to no snd @ top

dsky rd sndy sh w/ horz bdd in sndyr parts, bot 20 cm is grysh grn



ss- mg ss w/ mud clasts @ base and fish plates, bdng hard to see but blps low > and almost conv, ss cmt incr to base thin sh 9cm is hrd blky & grysh grn,

grysh grn mod fsl sh to hrd blky @ top

drb mod fsl sh, mainly broken up rubble

mixed drb-grysh grn mod blky sh fsl ip, abnt fish plates and scales,
bot 5cm is pl grn only, core is broken up rubble

fin up m-fg ss trough throu, top 11cm is shly and conv, many scat
mg snd in lower half of unit

grysh grn hrd blky sh, bot 10cm of unit is drb, contact is grad

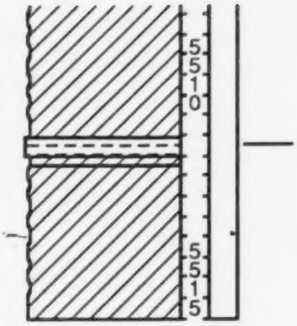
mixed drb-grysh grn mod fsl sh blky ip, scat fish scales throu, sndy ip, core is all broken up rubble

mostly drb hrd blky sndy sh w/ few grysh grn patchy areas

fin up unit, base conv shly fg ss, intb shly ss w/ grysh grn sh scale(1cm bds) horz bdd, upper sltst- shly sltst horz bdd to slightly wavy to top

drb-dsky rd mod blky sndy sh fsl ip, slks and microslks, few snd filled frac which are pl grn in col, upper 5cm is grysh grn bcmg mic to top

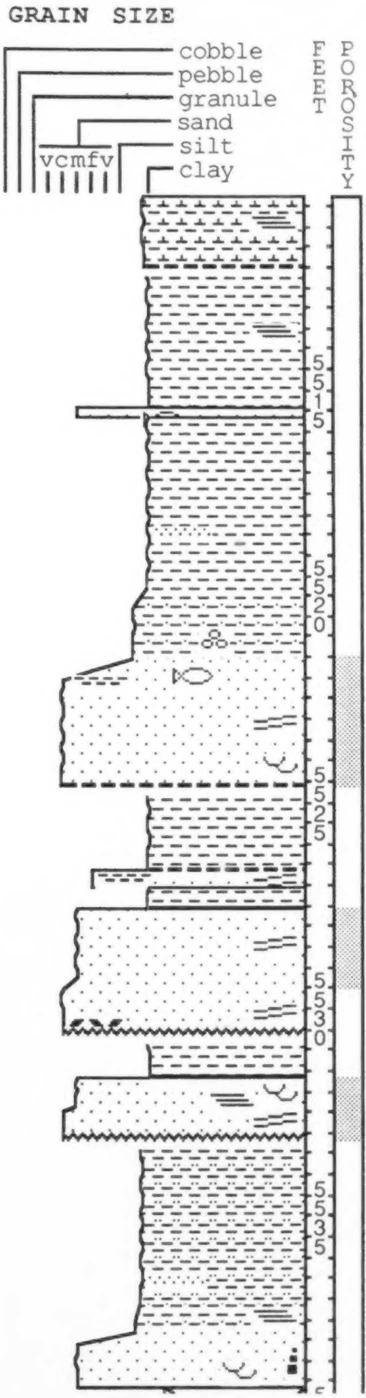
wavy horz bdd intb anhy sh, vgtd drb-tan & grysh grn ip, brec tan anhy at contact w/ upper sndy sh



blk med blky sh fis ip

Pan Am M-2 Nipisi

10-1-81-9w5



mixed ol gry-dyb horz lamd calc sh,

ol gry hrd blky sh, core box is rubble,

6cm dyb ss, well cmtd, scoured base, vert frac, bdng not vis psbl horz.

ol gry hrd blky sh., few thin .5cm sndy layers

dsky grn sndy sh, bcmg more sndy up, trace of limy clasts 1x.5cm @base

pyb cg ss, trough @ base and trough-low angle throu rest, upper 20cm is more muddier occas horz mud lams & fish bone, very var gr size throu many small 4cm fin up seq

pl grn hrd blky sh, same as thin sh unit below

pyb fg ss w/ sh lams, low angle bdng

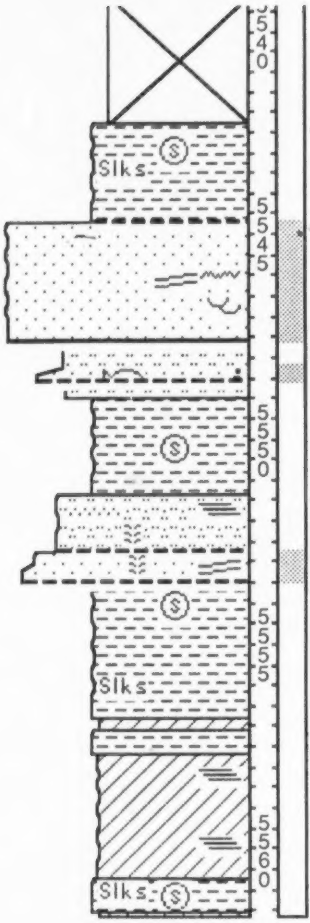
pl ol c-mg ss, low > thru, psbl high > @ base. sh rip up clasts @ base.

hrd blky sh, drb in mid and pl grn @ contacts with sand above and below

pyb vc-fg ss fin up, low angle bdng @ base, horz bdng @ top w/ mud lams,troughs near top

mainly drb-dsky rd sh sndy ip, grysh grn ip as blotches & top 5cm which is in contact w/ upper sand.

grysh grn sndy sh, horz-low angl bdng. ss below is pyb f-vcg ss, multiple fin up seq each 10cm, mud clast, muddier to top



drb med blky-fsl ip sh, sndy ip, slks & microslks throu

pyb, vcg ss w/ few fg areas which are scoured and capped by another vcg unit, mainly trough-pos low angle, fg units are low angle and muddier., well cmtd through crsr gr units

intb sltst & mg ss, fin up Three units

1. upper 20cm grsh grn sndy sltst
2. mid unit 7cm c-fg ss fin up pl grn
3. 10cm same as 1

drb med fis sh, blky, slks, mixed ip w/dsky rd

pl ol sndy slts, fluid escape features @ base, upper half sndy horz bdd.

pl ol m-fg ss, low > bdng, mud clasts @ base, few wtr escape features

dsky rd-drb mixed w/ pl grn med very fis sh due to the abnt slks

dsky grn med fis sh

horz lams anhy sh, tan, pl grn,

horz lams anhy sh,vgtd col, tan pl grn ol gry, dsky rd

blk hrd fis sh, slks-microslks